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Bulletin 160-93

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Governor
State of California

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Secretary for Resources
The Resources Agency

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Water Resources

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Foreword

In 1957, the Department of Water Resources published Bulletin 3, *The California Water Plan*, a comprehensive plan to guide and coordinate the current and future beneficial use of California's water resources. Bulletin 3 became the foundation for a series of water plan updates, now known as the Bulletin 160 series. The updates were published five times between 1966 and 1987. While they generally did not contain specific blueprints for water management and development, they described California's water use and supply at the time of their publication, projected future water needs, and provided information to guide beneficial use of the State's water resources. Each of the updates presented the overall outlook for water conditions throughout the State by examining total water supply and demand with the technology and analytical methods current at the time the updates were being prepared.

The scope of the updates has remained essentially the same; however, each took its own distinctive approach to water resources planning, reflecting the issues or concerns prevalent at the time the update was being developed. Bulletin 160-93, *The California Water Plan Update*, continues this tradition but differs from its predecessors by:

- estimating environmental water needs separately and accounting for these needs along with urban and agricultural water demands;
- recognizing and presenting water demand management methods, including conservation and land retirement, as additional means of meeting water needs; and,
- presenting two separate water balance scenarios. The first compares average demands with average supplies, which portrays the general picture. The shortage shown under average conditions is chronic and indicates the need for additional long-term measures. The second water balance compares drought year demands with drought year supplies. The shortage illustrated under drought conditions requires both long-term and short-term drought management measures, depending on local water service reliability requirements.

This water plan update consists of two volumes. Volume I focuses on statewide issues and reports the status of water use and supply. It also discusses the nature of water resource management planning, reliability and shortages, and it recommends options for balancing water demand and supply in the future. Volume II presents issues specific to each of the ten major hydrologic regions and chronicles water use and supply conditions by region.

Bulletin 160-93 was developed with extensive public involvement in accordance with amendments to Sections 10004 and 10005 of the California Water Code. An outreach advisory committee made up of representatives of urban, agricultural, and environmental interests was established in July 1992 to assist the Department of Water Resources in preparing Bulletin 160-93. The committee met regularly to review and comment on the content and adequacy of work in progress. Public hearings in each of the State's ten major hydrologic regions were held by the California Water Commission to receive comments from the public. Summaries of the comments received during the public hearing and comment period are appended to this report.

The inclusion of environmental water needs, the commitment to implementation of extensive water conservation measures, and the public involvement in developing this plan reflect current socioeconomic priorities. Water resource management has become increasingly complex, and this water plan update reveals many of the changes now shaping water management decisions in California.

David N. Kennedy
Director

A Letter from the California Water Commission

STATE OF CALIFORNIA - THE RESOURCES AGENCY   PETE WILSON, *Governor*

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April 1, 1994

Mr. David N. Kennedy, Director
Department of Water Resources
1416 Ninth Street, Room 1115
Sacramento, California 95814

Dear Mr. Kennedy:

The Water Code directs the Department of Water Resources to update the California Water Plan every five years, and it requires the Department to release a preliminary draft of the Plan for review and comment. As a part of this process, the Department, or at the Department's request, the California Water Commission must conduct a series of hearings with interested persons, local, State and Federal agencies and representatives of the diverse geographical areas and interests of the State. In response to these requirements, the Department prepared a draft of Bulletin 160-93, *California Water Plan Update*, which was released to the public for comments in November, 1993, and the California Water Commission conducted the public hearings on this Draft.

The members of the Commission conducted ten hearings in January and early February, 1994. One hearing was conducted in each of the State's ten major hydrologic regions. Comments were received from more than one hundred individuals. The Commission appreciates the detailed and cogent comments by many of those who participated in the hearings, which reflected a great deal of thought and analysis of the technical material and issues covered in the Draft.

The range of comments on the Draft, as well as issues raised in the Draft itself, point out that there is a serious and long-standing gap between planning on the one hand and construction and operation of water supply facilities on the other. To bring these together will require accommodation of engineering, economic and socio-political considerations. The comments highlight a number of serious problems in meeting California's water needs and strong political forces appear to be pulling in opposite directions. Bulletin 160 will provide factual information which should be helpful in reaching some reasonable accommodation. California can and must provide adequate supplies of good quality water to its citizens, industries, and lands in concert with a suitable environment for its fish and wildlife.

A Letter from the California Water Commission (continued)

Mr. David N. Kennedy
April 1, 1994
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The Commission believes that the Department of Water Resources staff has done an excellent job of developing and presenting the extensive material in the Draft. It represents the most thorough and comprehensive analysis of California's water needs and future supply options since the publication of Bulletin 1 in 1951, Bulletin 2 in 1955, and Bulletin 3 in 1957. Most witnesses at the hearings complimented the Department on the breadth and quality of the report and they indicated that the final report should be very helpful for their local planning efforts.

The Commission also appreciates the efforts of the Bulletin 160 Advisory Committee members who contributed substantial amounts of time and effort in reviewing and commenting on earlier administrative drafts. The quality of the Draft is in no small part the result of the Advisory Committee's efforts.

The Commission has considered the statements presented at each of the ten hearings, and has developed its own comments and recommendations on the Draft. These are set forth in the enclosed memorandum. We commend the Department's staff for its fine efforts, and we look forward to publication of the final document.

Sincerely,

Audrey Z. Tennis
Audrey Z. Tennis
Chair

Enclosure

Acknowledgment

In July 1992, the Department of Water Resources established an outreach advisory committee made up of people representing urban, agricultural, and environmental interests from various regions of the State to evaluate and advise DWR as to the adequacy of work in progress to update the California Water Plan.

DWR is indebted to the advisory committee members for providing critical feedback on the content and analyses required to produce the *California Water Plan Update*. While this report is a DWR product and does not necessarily reflect the viewpoint of each committee member nor the member's organization, the Department appreciates the committee's support of the balanced approach taken to develop this water plan.

DWR gratefully acknowledges the input from the members:

Bob Reeb, Chair	California Water Resources Association
George Baumli	State Water Contractors
Hal Carter	University of California Agricultural Issues Center
Cindy Chadwick	Department of Fish and Game
Grace Chan	The Metropolitan Water District of Southern California
Vernon Conrad	County Supervisors Association of California
Bill DuBois	California Farm Bureau
Lyle Hoag	California Urban Water Agencies
Laura King	Natural Resources Defense Council
John Krautkraemer	Environmental Defense Fund
Billy Martin	California Central Valley Flood Control Association
Shel Meyer	NorCal Fishing Guides and Sportsmen's Association
Christine Morioka	City of San Francisco Water Department
Larry Preston	North State Water Association
Stuart Pyle	Association of California Water Agencies
Jim Sequeira	City of Sacramento Department of Utilities
Charles Shreves	Imperial Irrigation District
Polly Smith	League of Women Voters
A. J. Yates	Department of Food and Agriculture

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Chapter 1

Summary of Volume I

For the first time in recent history, Californians are finding that existing water management systems are no longer able to provide sufficiently reliable water service to users. In most areas of the State, the 1987-92 drought: caused increased water conservation, and in some cases mandatory rationing, for urban water users; drastically curtailed surface water supplies for many agricultural water users; and strained environmental resources. The six-year drought stretched California's developed supply to its limits, yet innovative water banking, water transfers, water supply interconnections, and changes in project operations to benefit fish and wildlife all helped reduce the harmful effects of drought.

In light of the increased complexities in water resources planning brought about by these significant events, Water Code Section 10004 was amended in 1991 to require that the California Water Plan be updated every five years and that the Department of Water Resources "conduct a series of hearings with interested persons, organizations, . . . agencies, and representatives of the diverse geographical areas and interests of the state."

Since the last water plan update in 1987, *California Water: Looking to the Future, Bulletin 160-87*, evolving environmental policies have introduced considerable uncertainty about much of the State's water supply. For example, the winter-run chinook salmon and the Delta smelt were listed under the State and federal Endangered Species acts, imposing restrictions on Delta exports, and the Central Valley Project Improvement Act (PL 102-575) was passed in 1992, reallocating over a million acre-feet of CVP supplies for fish and wildlife. Other actions, such as the State Water Resources Control Board's Bay-Delta proceedings, and the federal Environmental Protection Agency's proposed Bay-Delta standards, suggest that even more stringent requirements could be imposed. These actions determine the export capability from California's most important water supply hub, the Sacramento-San Joaquin Delta, while also imposing restrictions on upstream diverters. The Delta is the source from which two-thirds of the State's population and millions of acres of agricultural land receive part or all of their supplies. Figure 1-1 shows major water project facilities in California.

The drought and actions to further protect fish and wildlife emphasized the need for a comprehensive water policy to guide California's water management and planning. On April 6, 1992, the governor announced his policy, which has provided general direction in developing demand management and supply augmentation alternatives put forth in this California Water Plan update.

The following overview summarizes each of the major elements (chapters) required to produce this water plan update. It begins by discussing the effects of recent

Figure 1-1. Water Project Facilities in California

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changes to the institutional framework for water management in California and continues by presenting: (1) California's existing water supplies along with water quality considerations, (2) the plan's assessment of the need and demand for water, and (3) options for balancing those demands with supply. Finally, recommendations are highlighted. Discussion of regional issues and the results of regional analyses used in developing the California Water Balance can be found in Volume II.

Effects of Recent Changes in the Institutional Framework

Chapter 2, *The Institutional Framework for Water Resource Management in California*, presents an overview of the major constitutional requirements, statutes, court decisions, and agreements that form the framework for many water resource management and planning activities in California.

Probably the most far reaching action affecting water resources management in California in the last decade was the federal listing of the winter-run chinook salmon and the Delta smelt, combined with the biological opinions on operations of the CVP and SWP that followed. The opinions effectively pre-empted short-term measures to provide environmental protection for the Bay-Delta as proposed by the State Water Resources Control Board's Draft Water Right Decision 1630. The actions and restrictions on water project operations contained in the biological opinions have immediate and future consequences on Delta export capability. The precise extent of those consequences is, thus far, unknown. Furthermore, the CVPIA reallocates a portion of CVP supplies for environmental purposes. About 400,000 af of the reallocation was used in 1993 to benefit winter-run salmon and Delta smelt; however, how the environmental water will be used on a long-term basis will be determined upon completion of a programmatic Environmental Impact Statement.

Other major actions (discussed in Chapter 2) that could have far reaching consequences are the EPA's proposed standards for the Bay-Delta estuary, future SWRCB Bay-Delta standards, and more stringent and costly drinking water quality standards. Recent decisions and laws that affect current water supply reliability are the Mono-Owens decision, which reduced the imports of supplies historically available to the South Coast Region, and a multitude of water management and water transfer legislation that has begun to open up the water market in California.

The Governor's Water Policy

Here are key elements of the Governor's water policy as announced on April 6, 1992. As the Governor stressed, each of these elements must be linked in such a way that no single interest (urban, agricultural, or environmental) gains at the expense of another.

- Fixing the Delta
- Reduction of Ground Water Overdraft
- Water Marketing and Transfers
- Additional Water for Fish and Wildlife
- Additional Storage Facilities
- Water Conservation
- Water Recycling
- Desalination
- Transfer of the federal Central Valley Project to State Control
- Colorado River Water Banking

California's Water Supplies

In the day-to-day planning and management of California's water resources, the term "reliability" is defined as a measure of a water service system's expected success in providing an adequate supply that meets expected demand and in managing shortages without serious detrimental effects. Reliability is not strictly a water supply characteristic because it includes demand management actions that can mitigate the effects of shortages (such as emergency water allocation programs during drought years). Given this definition, California generally had an adequately reliable supply to meet the 1990 level of urban, agricultural, and environmental water demands. However, in certain regions, the 1990 drought experience found some California communities and the environment suffering from a somewhat less than reliable drought supply to meet drought year needs. The following sections describe California's surface and ground water supplies and summarize water quality considerations.

Surface Water Supplies

The Sacramento and San Joaquin rivers have provided Californians with an average of nearly 15.5 maf annually for urban and agricultural uses. However, recent and future actions to protect aquatic species and reallocation of a portion of the Central Valley Project water supplies to the environment could reduce the existing annual supply availability for urban and agricultural uses by about 1 to 3 maf. This range envelops proposed additional environmental water needs.

Colorado River supplies to the South Coast Region for urban and agricultural uses could eventually decline from about 5.2 maf to California's apportionment of 4.4 maf annually. Historically, Arizona and Nevada have used less than their apportionment of water, making their unused supply of Colorado River water available to meet California's requirements. Southern California was spared from severe rationing during most of the 1987-92 drought primarily as a result of the 600,000 af annually of surplus and unused Colorado River water that was made available to the Metropolitan Water District of Southern California. Even with this supply, however, much of Southern California experienced significant rationing in 1991. Supplemental Colorado River water cannot be counted on to meet needs in the future as Arizona and Nevada continue to use more of their allocated share of Colorado River water.

In response to the 1987-92 drought, many creative approaches to cope with water shortages were implemented throughout California, including construction of more interconnections between local, State, and federal water delivery facilities. The City of San Francisco's connection to the SWP's South Bay Aqueduct allowed emergency drought supplies to be conveyed into the city's system for use by communities along the San Francisco peninsula. Toward the end of the drought, the City of Santa Barbara constructed a sea water desalination facility and received limited SWP supplies through an emergency interconnection and a series of exchanges with other water agencies. Throughout California, water agencies were buying and exchanging water to meet critical needs. The State Drought Water Bank played a vital role in meeting some of those critical water needs.

Prior to changes in water availability from the Sacramento-San Joaquin and Colorado river systems, California had roughly enough water to meet average annual urban and agricultural water demands at the 1990 level while complying with existing SWRCB standards, as specified in Water Rights Decision 1485. (See Chapter 2 for details about D-1485.) Chapter 3 summarizes historical water supply and discusses

Table 1-1. California Water Supplies with Existing Facilities and Programs
(Decision 1485 Operating Criteria for Delta Supplies)
(millions of acre-feet)

Supply	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
Surface								
Local	10.1	8.1	10.1	8.1	10.2	8.3	10.3	8.4
Local imports[1]	1.0	0.7	1.0	0.7	1.0	0.7	1.0	0.7
Colorado River	5.2	5.1	4.4	4.4	4.4	4.4	4.4	4.4
CVP	7.5	5.0	7.7	5.1	7.7	5.2	7.7	5.2
Other federal	1.2	0.8	1.3	0.8	1.3	0.8	1.3	0.8
SWP[1]	2.8	2.1	3.2	2.0	3.3	2.0	3.3	2.0
Reclaimed	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ground water[2]	7.1	11.8	7.1	12.0	7.2	12.1	7.4	12.2
Ground water overdraft[3]	1.3	1.3	—	—	—	—	—	—
Dedicated natural flow	27.2	15.3	27.4	15.4	27.4	15.4	27.4	15.4
TOTAL	63.5	50.4	62.4	48.9	62.7	49.1	63.0	49.4

(1) 1990 SWP supplies are normalized and do not reflect additional supplies delivered to offset the reduction of supplies from the Mono and Owens basins to the South Coast hydrologic region.
(2) Average ground water use is prime supply of ground water basins and does not include use of ground water which is artificially recharged from surface sources into the ground water basins.
(3) The degree future shortages are met by increased overdraft is unknown. Since overdraft is not sustainable, it is not included as a future supply.

the current supply system. Table 1-1 shows California's water supply with existing facilities and programs as operated in accordance with D-1485 for Delta supplies.

Average annual supplies at the 1990 level of development are about 63.5 maf (includes natural flows dedicated for instream use and ground water overdraft) and could decrease to 63.0 maf by 2020 without any additional facilities or programs. A possible substantial reduction in Colorado River supplies could be offset by short-term transfers and increased SWP Delta diversions, in addition to water management programs of the MWDSC. The 1990 level of development drought year supplies are about 50.4 maf and could decrease by about 1.0 maf by 2020 without additional storage and water management options. However, until comprehensive solutions to complex Delta problems are identified and implemented, SWP and CVP Delta diversions will continue to be impaired.

Ground Water Supply

California's ground water storage is about 850 maf, roughly 100 times the State's annual net ground water use, stored in some 450 ground water basins statewide. Probably less than half of this total is usable because of quality considerations and the cost of extraction. However, the large quantity of good-quality ground water makes it a crucial component of California's total water resource.

In a year of average precipitation and runoff, an estimated 15 maf of ground water is extracted and applied for agricultural, municipal, and industrial use. This is over 20 percent of the total applied water supply statewide, and ranges from 20 to 90 percent locally, depending on the area. However, because of deep percolation and extensive reuse of applied water, the 1990 level average annual net ground water use was about 8.4 maf, including about 1.3 maf of ground water overdraft. Overdraft estimates include 0.2 maf due to possible degradation of ground water quality in the trough of the San Joaquin Valley ground water basins. In drought years, the net use of

Table 1-2. Use of Ground Water by Hydrologic Region[1]
(thousands of acre-feet)

Hydrologic Region	1990 average	1990 drought	2000 average	2000 drought	2010 average	2010 drought	2020 average	2020 drought
North Coast	263	283	275	295	286	308	298	316
San Francisco Bay	100	139	126	174	160	174	165	174
Central Coast	688	762	694	769	695	776	698	781
South Coast	1,083	1,306	1,100	1,325	1,125	1,350	1,150	1,375
Sacramento River	2,496	2,865	2,463	2,985	2,426	3,033	2,491	3,038
San Joaquin River	1,098	2,145	1,135	2,202	1,156	2,227	1,161	2,252
Tulare Lake	915	3,773	918	3,758	921	3,726	926	3,758
North Lahontan	121	146	128	154	138	165	147	173
South Lahontan	221	252	220	237	226	271	258	271
Colorado River	80	80	79	79	80	80	79	79
TOTAL	7,100	11,800	7,100	12,000	7,200	12,100	7,400	12,200

(1) Average year ground water use represents use of prime supply of ground water basins. Ground water overdraft is not included.

ground water increases significantly to 13.1 maf (also including 1.3 maf of overdraft), which indicates the importance of the State's ground water basins as storage facilities to meet drought year water needs (see Chapter 4). Table 1-2 shows regional ground water use.

Between 1980 and 1990, annual ground water overdraft had been reduced by about 0.7 maf from the 1980 level of 2 maf. The reduction is mostly in the San Joaquin Valley and is due primarily to the benefits of imported supplies to the Tulare Lake Region, construction and operation of new reservoirs in the San Joaquin River Region during the 1960s and 1970s, and prudent management of surface and ground water resources, including conjunctive use of those supplies. Table 1-3 shows 1990 level regional overdraft. However, until key Delta issues are resolved and additional water management programs are implemented, the reductions in overdraft seen in the last decade in the San Joaquin Valley will reverse as more ground water is pumped to make

Table 1-3. Ground Water Overdraft by Hydrologic Region
(thousands of acre-feet)

Region	1990
North Coast	0
San Francisco Bay	0
Central Coast	240
South Coast	20
Sacramento River	30
San Joaquin	210
Tulare Lake	650
North Lahontan	0
South Lahontan	70
Colorado River	80
STATEWIDE	1,300

up for reductions in surface water supplies from the Delta. In the long-term, continued overdraft is not sustainable and must be addressed in local and State water management plans. As such, overdraft is not included as a future supply.

Efficient use of surface and ground water through conjunctive use programs has become an extremely important water management tool. Conjunctive use programs promise to be less costly than new traditional surface water projects because they increase the efficiency of existing water supply systems and generally have less adverse environmental impact than new surface water reservoirs. Conjunctive use programs must address potentially undesirable results such as loss of native vegetation and wetland habitat; adverse effects on third parties and fish and wildlife; land subsidence; and degradation of water quality in the aquifer. There are also questions about the feasibility and legal complexity of water transfers involving ground water.

Water Quality Considerations

Water quality considerations directly affect the quantities of water available for use in California. Poor water quality for the intended use has inherent costs, such as treatment and storage costs for drinking water, reduced crop yields, higher handling costs, and damage to fish and wildlife. The real challenge is to avoid these costs by protecting water sources from degradation in the first place.

Of critical importance to many Californians is the water quality of the Sacramento-San Joaquin Delta. Municipal and industrial waste discharges and agricultural drainage increase the salt content of water as it flows from higher elevations to the Delta. Sea water intrusion is a major source of salts in Delta supplies. Bromides from sea water are of particular concern because in combination with dissolved organic compounds present in soil they contribute to the formation of harmful disinfection byproducts of drinking water treatment. On the average, Delta influences are responsible for elevating the salt concentration at Banks Pumping Plant about 150 milligrams per liter above that of the fresh water inflows to the Delta. Most of the SWRCB's Delta water quality objectives relate to salinity. The SWP and CVP are required to operate to meet Delta salinity standards.

Disease-causing organisms and other harmful microorganisms which are found in raw water can pose serious health risks. New and more costly federal and State surface water treatment rules, effective in June 1993, require that all surface water supplied for drinking receive filtration, high-level disinfection, or both. The cost to construct new filtration facilities to meet new regulations can be quite high.

Human activities introduce a variety of pollutants which contribute to the degradation of water quality. Mining can be a major source of acids and toxic metals. Agricultural drainage may contain chemical residues, toxic elements, salts, nutrients, and elevated concentrations of chemicals which cause harmful disinfection byproducts. Municipal and industrial discharges, including storm runoff, are regulated by State and federal environmental protection laws and policies. Waste water must be treated to render it free of certain disease-carrying organisms and reduce its environmental impact. Unfortunately, normal waste water treatment plant processes may not completely remove all water-borne synthetic chemicals. The above water quality concerns and others are detailed in Chapter 5.

The Need and Demand for Water

Prior California Water Plan updates determined the existing "base case" for water supply and demand, then balanced forecasted future demand against existing supply and future supply and demand management options. To better illustrate overall demand and supply availability, two water supply and demand scenarios, an average year and a drought year, are presented for the normalized 1990 level of development and for projections to 2000, 2010, and 2020.

Shortages shown under average conditions are chronic shortages indicating the need for additional long-term water management measures. Shortages shown under drought conditions can be met by both long-term and short-term measures, depending on the frequency and severity of the shortage and water service reliability requirements. Urban, agricultural, and environmental water needs, along with water for recreation, are detailed in Part III of this report. The main conclusions are:

- California's population is projected to increase to 49 million people by 2020 (from about 30 million in 1990). Even with extensive water conservation, urban annual net water demand will increase by about 3.7 maf to 10.5 maf by 2020. Nearly half of the increased population is expected to occur in the South Coast Region, increasing that region's annual urban water demand by 1.8 maf. (See Chapter 6.)
- Irrigated agricultural acreage is expected to decline by nearly 400,000 acres, from the normalized 1990 level of 9.2 million acres to a 2020 level of 8.8 million acres, representing a 700,000-acre reduction from the 1980 level. Reductions in projected irrigated acreage are due primarily to urban encroachment onto agricultural land and land retirement in the western San Joaquin Valley where poor drainage and disposal conditions exist. Increases in agricultural water use efficiency, combined with reductions in agricultural acreage and shifts to growing lower-water-use crops, are expected to reduce agricultural annual net water demand by about 1.9 maf by 2020. (See Chapter 7.)
- The 1990 level and projections of environmental water needs to 2020 include water needs of managed fresh water wetlands (including increases in supplies for refuges resulting from implementation of the CVPIA), instream fishery requirements, Delta outflow, and wild and scenic rivers. Environmental water needs during drought years are considerably lower than average years, reflecting principally the variability of natural flows in the North Coast wild and scenic rivers. Average annual net water demand for environmental needs is expected to increase by 0.4 maf by 2020. Furthermore, regulatory agencies have proposed a number of changes in instream flow needs for major rivers, including the Sacramento and San

California's Water Supply Availability

Average year supply is the average annual supply of a water development system over a long period. For this report the SWP and CVP average year supply is the average annual delivery capability of the projects over a 70-year study period (1922-91). For a local project without long-term data, it is the annual average deliveries of the project during the 1984-1986 period. For dedicated natural flow, it is the long-term average natural flow for wild and scenic rivers, or it is environmental flows as required for an average year under specific agreements, water rights, court decisions, and congressional directives.

Drought year supply is the average annual supply of a water development system during a defined drought period. For this report, the drought period is the average of water years 1990 and 1991. For dedicated natural flow, it is the average of water years 1990 and 1991 for wild and scenic rivers, or it is environmental flows as required under specific agreements, water rights, court decisions, and congressional directives.

Joaquin. These proposed flow requirements are not necessarily additive; however, an increase from 1 to 3 maf is presented to envelop potential environmental water needs that could result from proposed additional instream needs and actions under way by regulatory agencies. (See Chapter 8.)

- With California's increasing population and higher levels of affluence since World War II, water-based recreation has become an integral part of satisfying urban society's ability and need for escape from the congestion of growing urban areas. State, federal, and local public water supply projects have helped to provide recreational facilities in addition to natural lakes and streams. In some cases, these projects have enhanced downstream flows during times of year when natural flows are diminished, thus creating whitewater rafting opportunities that were not possible before reservoir regulation. Often there are conflicting values and needs for the same river system. Recreation at reservoirs, natural lakes, and streams must be managed to prevent overuse and degradation. (See Chapter 9.)

Table 1-4 shows California's regional net water demands. A majority of the environmental net water demand occurs in the North Coast hydrologic region, reflecting the large dedicated natural flows of the North Coast wild and scenic rivers system, about 17.8 maf in an average year. The Tulare Lake Region has the largest net water demand for agriculture, about 7.7 maf in an average year, and the South Coast Region has the highest net water demand for urban use, about 3.5 maf in an average year. Dedicated instream flow under D-1485 makes up the largest portion of the San Francisco Bay Region's net water demand (about 4.6 maf), while urban and agricultural net water demands for the region amount to 1.3 maf.

Will There Be Enough Water?

Today, areas of the State relying on the Delta for all or a portion of their supplies find those supplies unreliable. Annual reductions in total water supply for urban and agricultural uses could be in the range of 500,000 af to 1 maf in average years and 2 to 3 maf in drought years. These reductions result mainly from compliance with the ESA biological opinions and proposed EPA Bay-Delta standards. While these impacts do not consider the potential reductions in Delta exports due to "take limits" under the biological opinions, they basically fall within the 1-to-3-maf range for proposed

Table 1-4. Net Water Demand by Hydrologic Region
(thousands of acre-feet)

Hydrologic Region	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
North Coast	20,035	10,159	20,182	10,306	20,213	10,337	20,238	10,364
San Francisco Bay	6,071	4,652	6,185	4,756	6,253	4,852	6,296	4,895
Central Coast	1,143	1,213	1,194	1,269	1,245	1,321	1,291	1,379
South Coast	4,379	4,521	4,812	4,974	5,319	5,499	5,903	6,110
Sacramento River	11,734	11,921	11,841	12,065	11,907	12,204	12,036	12,238
San Joaquin River	6,826	7,190	6,847	7,187	6,764	7,055	6,763	7,068
Tulare Lake	8,136	8,308	8,031	8,198	7,932	8,090	7,844	7,995
North Lahontan	514	566	518	571	520	573	537	590
South Lahontan	555	554	577	581	648	653	735	744
Colorado River	4,124	4,124	4,041	4,041	4,018	4,018	4,012	4,012
TOTAL	63,500	53,200	64,200	53,900	64,800	54,600	65,700	55,400

additional environmental demands for protection and enhancement of aquatic species. Such uncertainty of water supply delivery and reliability will continue until issues involving the Delta and other long-term environmental water management concerns are resolved.

In 1990, average annual supplies, including 1.3 maf of ground water overdraft, were generally adequate for 1990 level average demands. However, 1990 level drought-year supplies were insufficient to meet 1990 level drought-year demands, which is illustrated by a shortage of over 2.7 maf under D-1485 criteria in 1990. In the drought years 1991 and 1992, these shortages were reflected in urban mandatory water conservation (rationing), agricultural land fallowing and crop shifts, reduction of environmental flows, and short-term water transfers. Basically, shortages in supply exist today and are best illustrated by the year 2000 water budget.

After accounting for future reductions of 1.3 maf in net water demand resulting from implementation of urban Best Management Practices and agricultural Efficient Water Management Practices (discussed in Chapters 6 and 7), and another 0.1 maf reduction due to future land retirement, projected 2020 net demand for urban, agricultural, and environmental water needs amounts to 65.7 maf in average years and 55.3 maf in drought years. As noted, these demand amounts could increase by 1 to 3 maf.

By 2020, without additional facilities and improved water management, annual shortages of 3.7 to 5.7 maf could occur during average years depending on the outcome of various actions taking place to protect aquatic species. Average year shortages are considered chronic and indicate the need for implementing long-term water supply augmentation and demand management measures to improve water service reliability. Similarly, by 2020, annual drought year shortages could increase to 7.0 to 9.0 maf under D-1485 criteria, also indicating the need for long-term measures in addition to short-term drought management measures.

Water managers are looking into a wide variety of management actions to supplement, improve, and make better use of existing resources. The single most important action will be solving key issues in the Delta. This water plan update presents both long-term and short-term water management and supply augmentation options for meeting future water supply needs. Future water management options are presented in two levels to better reflect the status of investigations required to implement them.

- Level I options are those programs that have undergone extensive investigation and environmental analyses and are judged to have a higher likelihood of being implemented by 2020.
- Level II options are those programs that could fill the remaining gap shown in the balance between supply and urban, agricultural, and environmental water demands. These options require more extensive investigation and analyses of alternatives.

Implementation of Level I water management programs could reduce but not eliminate projected shortages. Included are short-term drought management options (demand reduction through urban rationing programs or water transfers that reallocate existing supplies through use of reserve supplies and agricultural land fallowing programs) and long-term demand management and supply augmentation options (increased water conservation, agricultural land retirement, additional waste water recycling, benefits of a long-term Delta solution, more conjunctive use programs, and additional south-of-the-Delta storage facilities). (Chapter 11 explains these options.) If all Level I options were implemented, there would still be a potential shortfall in annual supplies of about 2.1 to 4.1 maf in average years and 2.9 to 4.9 maf in drought years by 2020 that must be made up by Level II water supply augmentation and demand management programs. (Chapter 11 explains these programs.) Table 1-5 shows California's water supplies with Level I water management programs.

The California Water Budget, Table 1-6, compares total net water demand with supplies from 1990 through 2020. The water budget also indicates the potential magnitude of water shortages that can be expected in average and drought years if no actions are taken to improve water supply reliability. Figure 1-2 illustrates the water supply benefits of short- and long-term water management programs under Level I options and the need for further investigating and implementing Level II options.

Recommendations

The Delta is the hub of California's water supply infrastructure; key problems in the Delta must be addressed before several of the Level I options in the California Water Plan Update can be carried out. It is recommended that finding solutions to those problems be the first priority. Also, a proactive approach to improving fishery conditions—such as better water temperature control for spawning, better screening of diversions in the river system to reduce incidental take, and better timing of reservoir releases to improve fishery habitat—must be taken so that solutions to Delta problems mesh with basin-wide actions taken for improving fishery conditions. To that end, many of the restoration actions identified in the Central Valley Project Improvement Act for cost sharing with the State can improve conditions for aquatic species. Once a Delta solution is in place and measures for recovery of listed species have been initiated, many options requiring improved Delta export capability could become feasible.

Table 1-5. California Water Supplies with Level I Water Management Programs

(Decision 1485 Operating Criteria for Delta Supplies)

(millions of acre-feet)

Supply	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
Surface								
Local	10.1	8.1	10.2	8.2	10.2	8.3	10.3	8.4
Local imports(1)	1.0	0.7	1.0	0.8	1.0	1.0	1.0	1.0
Colorado River	5.2	5.1	4.4	4.4	4.4	4.4	4.4	4.4
CVP	7.5	5.0	7.7	5.2	7.7	5.2	7.7	5.2
Other federal	1.2	0.8	1.3	0.8	1.3	0.8	1.3	0.8
SWP(1)	2.8	2.1	3.4	2.1	3.9	3.0	4.0	3.0
Reclaimed	0.2	0.2	0.7	0.7	0.8	0.8	0.9	0.9
Ground water(2)	7.1	11.8	7.1	11.9	7.2	12.2	7.3	12.3
Ground water overdraft(3)	1.3	1.3	—	—	—	—	—	—
Dedicated natural flow	27.2	15.3	27.5	15.4	27.5	15.4	27.5	15.4
TOTAL	63.5	50.4	63.3	49.5	64.0	51.2	64.5	51.6

(1) 1990 SWP supplies are normalized and do not reflect additional supplies delivered to offset the reduction of supplies from the Mono and Owens basins to the South Coast hydrologic region.
(2) Average ground water use is prime supply of ground water basins and does not include use of ground water which is artificially recharged from surface sources into the ground water basins.
(3) The degree future shortages are met by increased overdraft is unknown. Since overdraft is not sustainable, it is not included as a future supply.

Table 1-6. California Water Budget
(millions of acre-feet)

Water Demand/Supply	***1990*** average	drought
Net Demand		
Urban—with 1990 level of conservation	6.8	7.1
—reductions due to long-term conservation measures (Level I)	0	0
Agricultural—with 1990 level of conservation	26.8	28.2
—reductions due to long-term conservation measures (Level I)	0	0
—land retirement in poor drainage areas of San Joaquin Valley (Level I)	—	—
Environmental	28.4	16.4
Other[1]	1.5	1.5
Subtotal	63.5	53.2
Proposed Additional Environmental Water Demands[2]		
Case I - Hypothetical 1 MAF	—	—
Case II - Hypothetical 2 MAF	—	—
Case III - Hypothetical 3 MAF	—	—
Total Net Demand	63.5	53.2
Case I	—	—
Case II	—	—
Case III	—	—
Water Supplies w/Existing Facilities Under D-1485 for Delta Supplies		
Developed Supplies		
Surface Water[3]	27.9	22.1
Ground Water	7.1	11.8
Ground Water Overdraft[3]	1.3	1.3
Subtotal	36.3	35.2
Dedicated Natural Flow	27.2	15.3
TOTAL Water Supplies	63.5	50.5
Demand/Supply Balance	0.0	-2.7
Case I	—	—
Case II	—	—
Case III	—	—
Level 1 Water Management Programs[4]		
Long-term Supply Augmentation		
Reclaimed	—	—
Local	—	—
Central Valley Project	—	—
State Water Project	—	—
Short-Term Drought Management		
Potential Demand Management	—	1.0
Drought Water Transfers	—	0.8
Subtotal - Level I Water Management Programs	—	1.8
Net Ground Water or Surface Water Use Reduction Resulting from Level I Programs	—	0.0
NET TOTAL Demand Reduction/Supply Augmentation	0.0	1.8
Remaining Demand/Supply Balance Requiring Level II Options	0.0	-0.9
Case I	—	—
Case II	—	—
Case III	—	—

(1) Includes major conveyance facility losses, recreation uses, and energy production.
(2) Proposed Environmental Water Demands—Case I-III envelop potential and uncertain demands and have immediate and future consequences on supplies from the Delta, beginning with actions in 1992 and 1993 to protect winter run salmon and delta smelt (actions which could also protect other fish species).

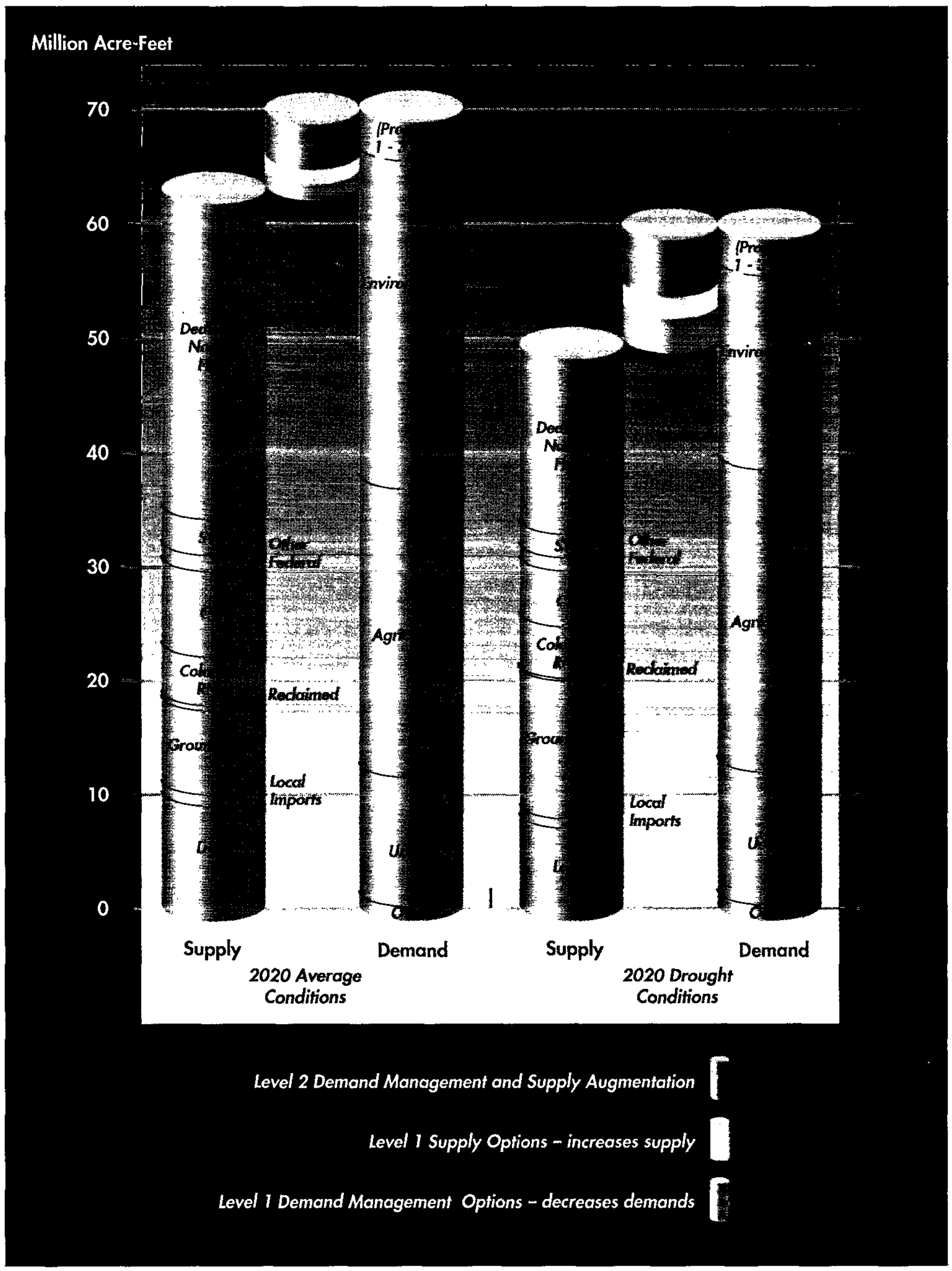
Table 1-6. California Water Budget
(millions of acre-feet)

2000 average	2000 drought	2010 average	2010 drought	2020 average	2020 drought
8.3	8.7	9.9	10.3	11.4	11.9
-0.4	-0.4	-0.7	-0.7	-0.9	-0.9
26.4	27.7	25.8	27.1	25.4	26.6
-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
28.8	16.8	28.8	16.8	28.8	16.8
1.5	1.4	1.5	1.4	1.5	1.4
64.3	53.9	64.9	54.5	65.7	55.3
1.0	1.0	1.0	1.0	1.0	1.0
2.0	2.0	2.0	2.0	2.0	2.0
3.0	3.0	3.0	3.0	3.0	3.0
—	—	—	—	—	—
65.3	54.9	65.9	55.5	66.7	56.3
66.3	55.9	66.9	56.5	67.7	57.3
67.3	56.9	67.9	57.5	68.7	58.3
27.8	21.5	28.1	21.6	28.2	21.7
7.1	12.0	7.2	12.1	7.4	12.2
—	—	—	—	—	—
34.9	33.5	35.3	33.7	35.6	33.9
27.4	15.4	27.4	15.4	27.4	15.4
62.3	48.9	62.7	49.1	63.0	49.3
—	—	—	—	—	—
-3.0	-6.0	-3.2	-6.4	-3.7	-7.0
-4.0	-7.0	-4.2	-7.4	-4.7	-8.0
-5.0	-8.0	-5.2	-8.4	-5.7	-9.0
0.5	0.5	0.6	0.6	0.8	0.8
0.0	0.1	0.0	0.3	0.0	0.3
0.0	0.0	0.0	0.0	0.0	0.0
0.2	0.1	0.6	1.0	0.7	1.0
—	1.0	—	1.0	—	1.0
—	0.8	—	0.8	—	0.8
0.7	2.5	1.3	3.8	1.5	3.9
0.1	0.0	0.1	0.2	0.1	0.2
0.7	2.5	1.4	4.0	1.6	4.1
—	—	—	—	—	—
-2.3	-3.5	-1.8	-2.4	-2.1	-2.9
-3.3	-4.5	-2.8	-3.4	-3.1	-3.9
-4.3	-5.5	-3.8	-4.4	-4.1	-4.9

(3) The degree future shortages are met by increased overdraft is unknown. Since overdraft is not sustainable, it is not included as a future supply.
(4) Protection of fish and wildlife and a long-term solution to complex Delta problems will determine the feasibility of several water supply augmentation proposals and their water supply benefits.

Figure 1-2. California Water Balance

Note: Water supplies are based on SWRCB D-1485 operating criteria for Delta exports. Tables 11-1, 11-5, and 11-8 (Chapter 11) list Level I and Level II options.



Following are the major Level I options recommended for implementation to help meet California's water supply needs to 2020, along with their potential benefits. Many of them still require additional environmental documentation and permitting, and in some instances, alternative analyses. Before many of these programs can be implemented, environmental water needs must be identified and prioritized and funding issues addressed.

Demand Management

- Water conservation—by 2020, implementation of urban BMPs could reduce annual urban applied water demand by 1.3 maf, and net water demand by 0.9 maf,

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after accounting for reuse. Implementation of agricultural EWMPs, which increase agricultural irrigation efficiencies, could reduce agricultural applied water demands by 1.7 maf and net water demand by 0.3 maf, after accounting for reuse. In addition, lining of the All-American Canal will reduce net water demand by 68,000 af.

- Land fallowing and water bank programs during droughts—temporary, compensated reductions of agricultural net water demands and purchases of surplus water supplies could reallocate at least 0.6 maf of drought-year supply. However, such transfers are impaired until solutions to Delta transfer problems are identified and implemented.
- Drought demand management—voluntary rationing averaging 10 percent statewide during drought could reduce annual drought-year urban applied and net water demand by 1.0 maf in 2020.
- Land retirement—retirement of 45,000 acres with poor subsurface drainage and disposal on the western San Joaquin Valley could reduce annual applied and net water demand by 0.13 maf by 2020.

Supply Augmentation

- Water reclamation—plans for an additional 1.2 maf of water recycling and ground water reclamation by 2020 could provide annual net water supplies of nearly 0.8 maf after accounting for reuse.
- Solutions to Delta water management problems—improved water service reliability and increased protection for aquatic species in the Delta could provide 0.2 to 0.4 maf annually of net water supplies (under D-1485) and make many other water management options feasible, including water transfers.
- Conjunctive use—more efficient use of major ground water basins through programs such as the Kern Water Bank could provide 0.4 maf of drought-year net water supplies (under D-1485).
- Additional storage facilities—projects such as Los Banos Grandes (SWP), could provide 0.3 maf of average and drought-year net water supplies (under D-1485), and Domenigoni Valley Reservoir (MWDSC) could provide 0.3 maf of drought-year net water supplies.

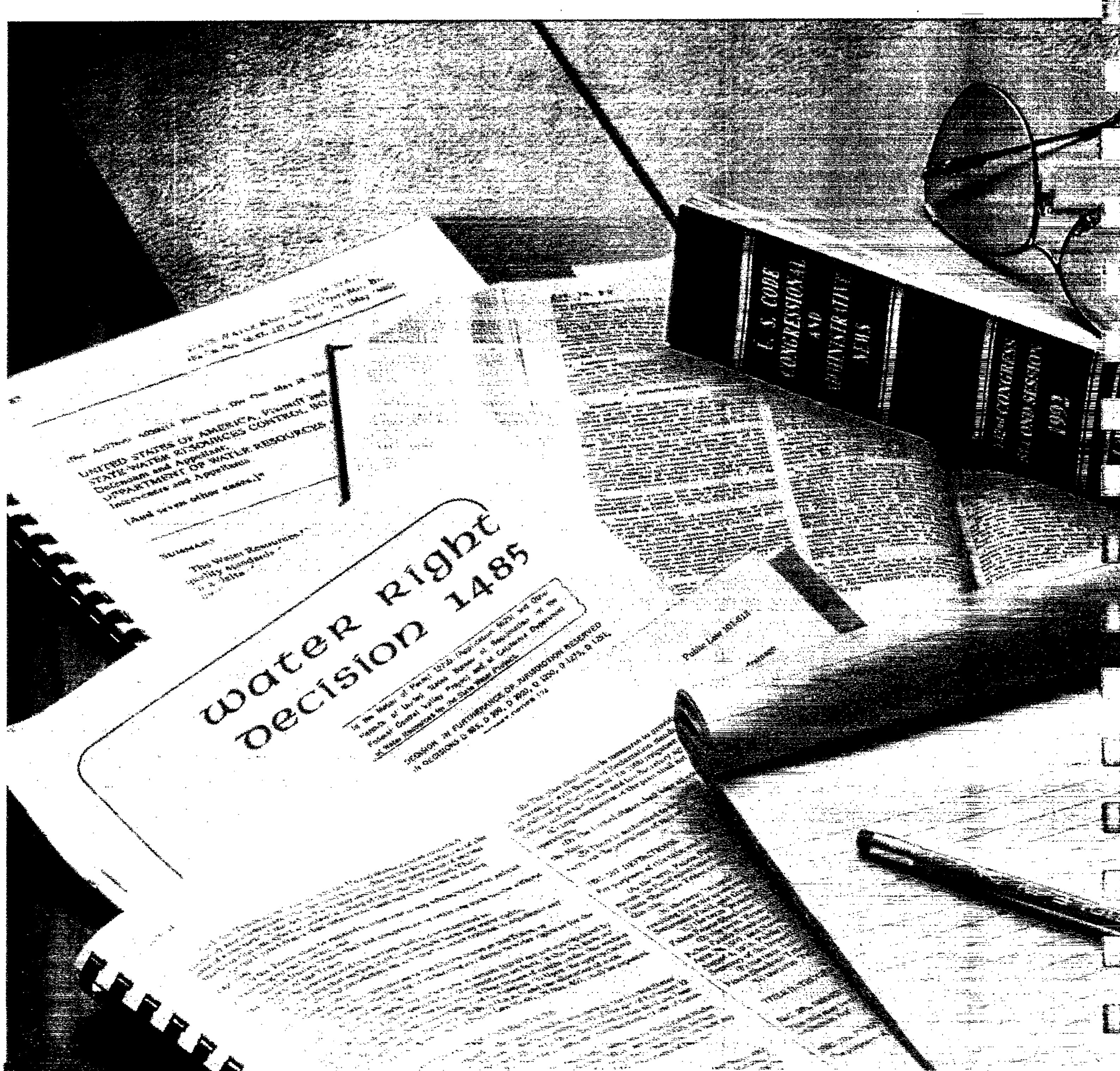
In the short-term, those areas of California relying on the Delta for all or a portion of their supplies face uncertain water supply reliability due to the unpredictable outcome of actions being undertaken to protect aquatic species and water quality. At the same time, California's water supply infrastructure is limited in its capacity to transfer marketed water through the Delta due to those same operating constraints. Until solutions to complex Delta problems are identified and put in place, and demand management and supply augmentation options are implemented, many Californians will experience more frequent and severe water supply shortages. For example, in 1993, an above-normal runoff year, environmental restrictions limited CVP deliveries to 50 percent of contracted supply for federal water service contractors in the area from Tracy to Kettleman City. Such limitations of surface water deliveries from the Delta will exacerbate ground water overdraft in the San Joaquin River and Tulare Lake regions because ground water is used to replace much of the shortfall in surface water supplies. In addition, water transfers within these areas will become more common as farmers seek to minimize water supply impacts on their operations. In urban areas, water conservation and water recycling programs will be accelerated to help offset short-term reliability needs.

C-037658

Finally, it is recommended that Level II options be evaluated, expanded to include other alternatives, and planned for meeting the potential range of average-year shortages of 2.1 to 4.1 maf and the potential range of drought-year shortages of 2.9 to 4.9 maf. Level II options include demand management and supply augmentation measures such as additional conservation, land retirement, increased water recycling and desalting, and surface water development. Several mixes of State and local Level II options should be investigated, and their economic feasibility ascertained, to address the range of demand and supply uncertainty illustrated in the California Water Budget. Such uncertainty will affect the identification and selection of Level II options needed to meet California's future water supply needs.

C-037660

Water Right Decision 1485 established salinity control standards for the Sacramento–San Joaquin Delta and Suisun Marsh. D-1485, the recently enacted Central Valley Project Improvement Act of 1992, and biological opinions under the Endangered Species Act all affect the timing and amount of water flowing through the Delta at any given time.



Chapter 2

The Institutional Framework for Water Resource Management in California

Water resource management in California is at a critical juncture as evolving policies and physical limits of the State's water supply infrastructure collide. Three major interest groups—urban, agricultural, and environmental—must work their way through California's institutional framework toward solutions that should benefit all Californians and their environment.

Since 1957, when the first comprehensive California Water Plan was published, attitudes toward and methods for managing the State's natural resources have gone through many changes. Californians have become more environmentally sensitive, as reflected in statutes such as the California Environmental Quality Act, the State Endangered Species Act, and the State Wild and Scenic Rivers Act.

The situation in the Sacramento-San Joaquin Delta is a prime example of an area where concerns about aquatic species compete with urban and agricultural water supply needs. The Delta provides valuable habitat and migration corridors for many species, including the winter-run salmon and Delta smelt, which are listed under the State and federal Endangered Species Acts. The Sacramento split-tail is also being considered for listing under the State and federal acts because of its low populations. Natural resource managers are looking for ways to help these species recover. Biological opinions have been issued under the federal Endangered Species Act; these opinions affect how water supply projects in the Delta are operated. Essentially, the opinions have increased the amount of water allocated to environmental uses in the Delta over SWRCB D-1485, and they affect when water projects in the Delta can pump or convey the supplies that eventually serve about two-thirds of California's population and much of its farmland. California's population will require even more water as it grows by nearly 60 percent by the year 2020, making it clear to resource managers that something must be done to address water supply reliability for urban, agricultural, and environmental needs in the Delta.

In California, water use and supplies are controlled and managed under an intricate system of federal and State laws. Common law principles, constitutional provisions, State and federal statutes, court decisions, and contracts or agreements all govern how water is allocated, developed, or used. All of these components, along with the responsible State, federal, and local agencies, compose the institutional framework for allocation and management of water resources in California.

This chapter presents an overview of California's institutional framework for managing water resources in California. It highlights some of the changes that have occurred over the last decade, as new statutes have been enacted and earlier laws, decisions, and agreements reinterpreted. Summarized here are major constitutional requirements, statutes, court decisions, and agreements that form the groundwork for many water resource management and planning activities. (General references and citations to the laws and cases discussed are contained in Appendix A.)

Allocation and Management of California's Water Supplies

The following subsections condense the basic water rights laws and doctrines governing allocation and use of California's water supplies.

California Constitution Article X, Section 2

The keystone to California's water law and policy, Article X, Section 2 of the California Constitution, requires that all uses of the State's water be both reasonable and beneficial. It places a significant limitation on water rights by prohibiting the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water.

Riparian and Appropriative Rights

California operates under a dual system of water rights for surface water which recognizes both the doctrine of riparian rights and appropriative rights. Under the riparian doctrine, the owner of land has the right to divert but not store a portion of the natural flow of water flowing by his land for reasonable and beneficial use upon his land adjacent to the stream and within its watershed, subject to certain limitations. Generally, all riparian water right holders must reduce their water use in times of water shortages. Under the prior appropriation doctrine, a person has a right to divert, store, and use water regardless of whether the land on which it is used is adjacent to a stream or within its watershed, provided that the water is used for reasonable and beneficial uses and is surplus to water from the same stream used by earlier appropriators. The rule of priority between appropriators is "first in time is first in right."

Water Rights Permits and Licenses

The Water Commission Act, which took effect in 1914 following a referendum, recognized the overriding interest of the people in the waters of the state but provided that private rights to use the water may be acquired in the manner provided by law. The act established a system of state-issued permits and licenses to appropriate water. Amended over the years, it now appears in Division 2 (Commencing with Section 1000) of the Water Code. These provisions place responsibility for administering appropriative water rights with the State Water Resources Control Board; however, the permit and license provisions do not apply to pre-1914 appropriative rights (those initiated before the act took effect in 1914). The act also provides procedures for adjudication of water rights, including court references to the State Water Resources Control Board and statutory adjudications of all rights to a stream system.

Ground Water Management

Generally, ground water is available to any person who owns land overlying the ground water basin. Ground water management in California is accomplished either by a judicial adjudication of the respective rights of overlying users and exporters, or by local management of rights to extract and use ground water as authorized by statute or agreement. Most of the larger ground water basins in Southern California and the San Francisco Bay area are managed either pursuant to a court adjudication or by an agency with statutory powers; however, most basins in Northern California are not so managed. Statutory management may be either by powers granted to a public agency that also manages surface water, or by a ground water management agency created expressly for that purpose.

In 1992, the Legislature repealed the water code sections that authorized management in specific critically overdrafted basins and adopted new sections to authorize any local agency which provides water service to adopt a ground water management plan if the ground water is not subject to management under other provisions of law or a court decree. Specific notice and hearing procedures must be followed. If protesting landowners represent more than 50 percent of the assessed valuation of land within the local agency, the ground water management plan may not be adopted. Elements of a plan may include control of saline water intrusion, identification and protection of well head and recharge areas, regulation of the migration of contaminated water, provisions for abandonment and destruction of wells, mitigation of overdraft, replenishment, monitoring, facilitating conjunctive use, identification of well construction policies, and construction of cleanup, recharge, recycling, and extraction projects by the local agency.

Public Trust Doctrine

In the 1980s, the Public Trust Doctrine was used by courts to limit traditional water rights. Under the Equal Footing Doctrine of the U.S. Constitution, each state has title to tidelands and the beds of navigable lakes and streams within its borders. The Public Trust Doctrine—recognized in some form by most states—embodies the principle that the state holds title to such properties within the state in trust for the beneficial use of the public and that public rights of access to and use of tidelands and navigable waters are inalienable. Traditional public trust rights include navigation, commerce, and fishing. California law has expanded the traditional public trust uses to include protection of fish and wildlife, preserving trust lands in their natural condition for scientific study and scenic enjoyment, and related open-space uses.

In 1983, the California Supreme Court extended the public trust doctrine's limitation on private rights to appropriative water rights. In *National Audubon Society v. Superior Court of Alpine County*, the court held that water right licenses held by the City of Los Angeles to divert water from streams tributary to Mono Lake remain subject to ongoing State supervision under the public trust doctrine. The court held that public trust uses must be considered and balanced when rights to divert water away from navigable water bodies are considered. The court also held that California's appropriative rights system and the public trust doctrine embody important precepts which "...make the law more responsive to the diverse needs and interests involved in planning and allocation of water resources." Consequently, in issuing or reconsidering any rights to appropriate and divert water, the State must balance public trust needs with the needs for other beneficial uses of water.

What Is Navigable?

The law has a number of different—and often confusing—definitions of "navigable" rivers and lakes (all tidal areas are considered navigable). For purposes of determining state title to the beds of rivers and lakes, they must have been capable of carrying commerce at the time the state entered the union. "Commerce" includes more than boats carrying persons and cargo. The courts have found streams to be "navigable" where they have carried saw logs or shingle bolts. For purposes of some federal regulatory programs, a waterway must have carried, or be capable of carrying, interstate commerce. Other federal regulatory programs (e.g., the Federal Power Act) include waterways which could carry interstate commerce with reasonable modifications. Finally, the Clean Water Act defines "navigable" waters to include all waters of the United States which may affect or be affected by interstate commerce. This includes most water bodies in the nation.

Since the 1983 *National Audubon* decision, the public trust doctrine has been involved in several other cases. In *United States v. State Water Resources Control Board* (commonly referred to as the *Racanelli Decision* and discussed later in this chapter), the State Court of Appeal reiterated that the public trust doctrine is a significant limitation on water rights. The public trust doctrine was also a basis for the decision in *Environmental Defense Fund v. East Bay Municipal Utility District.* In this case, EDF claimed that EBMUD should not contract with the U.S. Bureau of Reclamation for water diverted from the American River upstream of where it flowed through the Sacramento urban area in a manner that would harm instream uses including recreational, scenic, and fish and wildlife preservation purposes. The Superior Court upheld the validity of EBMUD's contract with USBR but placed limitations on the timing and amounts of deliveries to EBMUD. As a result of these cases, the SWRCB now routinely implements the public trust doctrine through regulations and through appropriate terms and conditions in water rights permits and licenses.

The public trust decisions reflect changes in our attitudes about using water resources. The earliest cases involved rights of public access to tidelands around San Francisco Bay and San Pablo Bay. Later cases involved public trust rights to inland water bodies such as Clear Lake and Lake Tahoe. Modification of water rights is the most recent application of this doctrine.

Federal Power Act

The Federal Power Act has, at times, conflicted with the administration of State water rights involving hydroelectric projects. The act creates a federal licensing system administered by the Federal Energy Regulatory Commission and requires that a license be obtained for nonfederal hydroelectric projects proposing to use navigable waters or federal lands. The act contains a clause modeled after a clause in the Reclamation Act of 1902, which disclaims any intent to affect state water rights law.

In a number of decisions dating back to the 1940s, the U.S. Supreme Court held that provisions of the Reclamation Act and the Federal Power Act preempted inconsistent provisions of state law. Decisions under both acts found that these clauses were merely "saving clauses" which required the United States to follow minimal state procedural laws or to pay just compensation where vested non-federal water rights are taken. However, in *California v. United States*, the U.S. Supreme Court overturned a number of earlier Supreme Court decisions which found that the Reclamation Act substantially preempts state water law. It held that the Reclamation Act clause requires the Bureau of Reclamation to comply with conditions in state water rights permits unless those conditions conflict with "clear Congressional directives."

In *California v. FERC* (1990), commonly referred to as the *Rock Creek Decision*, the U.S. Supreme Court rejected California's argument that the Federal Power Act clause required deference to state water law, as the Reclamation Act's did. The court pointed out that the Federal Power Act had been construed in a number of cases to preempt inconsistent state law, beginning with *First Iowa Hydroelectric Cooperative v. Federal Power Commission* (1946)

First Iowa involved a state law which required that water be returned to a river at the first available point below the dam in order to receive a state permit. The project licensed by the FPC did not do this. The Supreme Court held that the Federal Power Act's reference to state law was merely a "savings clause" intended only to require compensation if vested property rights are taken. In all other respects, the Federal Power Act could supersede inconsistent state laws. The Court noted that Iowa law sought to regulate ". . .the very requirements of the project which the Congress has placed in the discretion of the Federal Power Commission."

Thus, in *California v. FERC*, the court declined to interpret the Federal Power Act in the same manner as the Reclamation Act. It distinguished between the two acts, finding that the Federal Power Act envisioned a broader and more active federal oversight role than did the Reclamation law.

The Federal District Court case of *Sayles Hydro Association v. Maughan* (February 1993), reinforced this view by holding that federal law has "occupied the field," preventing any state regulation of federally licensed power projects other than determining proprietary water rights. In *Sayles*, the SWRCB refused to issue a permit to the proponents of a hydro project until they had completed numerous environmental reports and studies. The proponents sought and received a declaratory judgment that no more environmental reports were necessary because the Board did not have the authority to impose environmental conditions in the permit beyond what was required in the already-issued FERC license.

Preemption of state law by terms and conditions in Federal Power Act licenses is likely to remain a significant problem for water management in the western states. There have been instances where holders of Federal Power Act licenses have claimed preemption from state safety of dams requirements, minimum stream flow requirements, and state designation of wild and scenic streams.

Area of Origin Statutes

During the years when California's two largest water projects, the Central Valley Project and State Water Project, were being developed, area of origin legislation was enacted to protect local Northern California supplies from being depleted as a result of the projects. County of origin statutes provide for the reservation of water supplies for counties in which the water originates when, in the judgment of the State Water Resources Control Board, an application for the assignment or release from priority of State water right filings will deprive the county of water necessary for its present and future development. Watershed protection statutes are provisions which require that the construction and operation of elements of the Federal Central Valley Project and the State Water Project not deprive the watershed, or area where water originates, or immediately adjacent areas which can be conveniently supplied with water, of the prior right to water reasonably required to supply the present or future beneficial needs of the watershed area or any of its inhabitants or property owners.

The Delta Protection Act, enacted in 1959 (not to be confused with the Delta Protection Act of 1992, which relates to land use), declares that the maintenance of an adequate water supply in the Delta—to maintain and expand agriculture, industry, urban, and recreational development in the Delta area and provide a common source of fresh water for export to areas of water deficiency—is necessary for the peace, health, safety, and welfare of the people of the State, subject to the County of Origin and Watershed Protection laws. The act requires the State Water Project and the federal CVP to provide an adequate water supply for water users in the Delta through salinity control or through substitute supplies in lieu of salinity control.

In 1984, additional area of origin protections were enacted covering the Sacramento, Mokelumne, Calaveras, and San Joaquin rivers; the combined Truckee, Carson, and Walker rivers; and Mono Lake. The protections prohibit the export of ground water from the combined Sacramento River and Sacramento-San Joaquin Delta basins, unless the export is in compliance with local ground water plans. Also, Water Code Section 1245 holds municipalities liable for economic damages resulting from their diversion of water from a watershed.

The Current Regulatory and Legislative Framework

California's developed water supplies have become less reliable and more costly for urban and agricultural users as State and federal regulations to protect the public and its environment have increased. Environmental actions and regulations to protect both water quality and fish and wildlife have had far reaching effects on water use and management and involve several regulatory agencies. A few important examples are:

- Fish and Wildlife

  U.S. Fish and Wildlife Service and National Marine Fisheries Service enforce rules and regulations under the federal Endangered Species Act.

  California Department of Fish and Game enforces rules and regulations under the State Endangered Species Act.

- Water Quality

  State Water Resources Control Board and Regional Water Quality Control Boards enforce rules and regulations under the Porter–Cologne Water Quality Control Act.

  Federal Environmental Protection Agency has delegated primary water quality control and enforcement authority under the Clean Water Act to the SWRCB and its regional boards.

Regulatory actions, in combination with costs of compliance, have brought California's water development close to a standstill for nearly 15 years. During this time, water resource managers have implemented a number of strategies to help Californians become more efficient in their water use, thus stretching existing supplies. But California's increased demand for water to meet the needs of a growing population and to protect the environment all point to the necessity of addressing the problems and moving forward with cost effective and environmentally sound water supply development combined with more efficient water management.

Many of the current issues regarding the storage, allocation, distribution, and use of water in California involve environmental concerns. Environmental laws are inextricably intertwined in all of the State's major water supply programs, and environmental concerns play a major role in water policy and planning. Following is a summary of the major environmental laws influencing water supply facility planning, construction, and operation.

Protection of Fish and Wildlife

Endangered Species Act. Under the federal ESA, an endangered species is one that is in danger of extinction in all or a significant part of its range, and a threatened species is one that is likely to become endangered in the near future. The ESA is designed to preserve endangered and threatened species by protecting individuals of the species and their habitat and by implementing measures that promote their recovery.

The ESA sets forth a procedure for listing species as threatened or endangered. Final listing decisions are made by the United States Fish and Wildlife Service or the National Marine Fisheries Service. Presently over 650 species have been listed in the United States, of which 110 are native to California—the largest number in any state.

Once a species is listed, Section 7 of the act requires that federal agencies, in consultation with the U.S. Fish and Wildlife Service or National Marine Fisheries Service, ensure that their actions do not jeopardize the continued existence of the species or

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habitat critical for the survival of that species. The federal wildlife agencies are required to provide an opinion as to whether the federal action would jeopardize the species. The opinion must include reasonable and prudent alternatives to the action that would avoid jeopardizing the species' existence. Federal actions subject to Section 7 include issuance of federal permits such as the dredge and fill permit required under Section 404 of the federal Clean Water Act, which requires that the project proponent demonstrate that there is no feasible alternative consistent with the project goals that would not affect listed species. Mitigation of the proposed project is not considered until this hurdle is passed.

State agencies and private parties are also subject to the ESA. Section 9 of the ESA prohibits the "take" of endangered species and threatened species for which protective regulations have been adopted. Take has been broadly defined to include actions that harm or harass listed species or that cause a significant loss of their habitat. State agencies and private parties are generally required to obtain a permit from the USFWS or NMFS under Section 10(a) of the ESA before carrying out activities that may incidentally result in the take of listed species. The permit normally contains conditions to avoid take of listed species and to compensate for habitat adversely impacted by the activities.

The ESA has been interpreted to apply not just to new projects, but also to ongoing project operation and maintenance. For example, maintenance activities along the California Aqueduct right-of-way may impact the San Joaquin kit fox, the blunt-nose leopard lizard, and the Tipton kangaroo rat, all species that have been listed as endangered. DWR initiated the Section 10(a) process to obtain a permit for the incidental take of species resulting from maintenance activities along the California Aqueduct despite measures DWR takes to reduce or eliminate take. Another example is federal, State, and local operations in the Delta and upstream Sacramento River that are affected by biological opinions to protect the winter-run salmon and the Delta smelt.

California Endangered Species Act. The California Endangered Species Act is similar to the federal ESA and must be complied with in addition to the federal ESA. Listing decisions are made by the California Fish and Game Commission.

All state lead agencies are required to consult with the Department of Fish and Game about projects that impact State listed species. DFG is required to render an opinion as to whether the proposed project jeopardizes a listed species and to offer alternatives to avoid jeopardy. State agencies must adopt reasonable alternatives unless there are overriding social or economic conditions that make such alternatives infeasible.

Many California species are both federally listed and State listed. CESA directs DFG to coordinate with the USFWS and NMFS in the consultation process so that consistent and compatible opinions or findings can be adopted by both federal and State agencies.

Natural Community Conservation Planning. Adopted in 1991, California's Natural Community Conservation Planning Act establishes a program to identify the habitat needs of species before they become listed as threatened or endangered, and to develop appropriate voluntary conservation methods compatible with development and growth. This program is designed to preserve habitat for the variety of species that are dependent upon each other. Participants in the program develop plans to protect certain habitat and will ultimately enter into agreements with DFG to ensure that the plans will be carried out. Plans must be created so that they are consistent with endangered species laws. A pilot program has been established in Riverside, Orange, and San Bernardino counties for the Coastal Sage Scrub, which exists in a habitat that has been diminishing. A number of endangered species, including the gnatcatcher, depend on this habitat. The Secretary of the U.S. Department of the Interior has endorsed this process, which may evolve into the approach of the future. Participation in these plans is not mandatory.

The Natural Conservation Planning Act is likely to play an important role in water development in the future. Water suppliers may participate in plans for habitat impacted directly by new water projects and indirectly in the areas that receive water supplies.

Dredge and Fill Permits. Section 404 of the federal Clean Water Act regulates the discharge of dredged and fill materials into waters of the United States, including wetlands. The term "discharge of dredged and fill material" has been defined broadly to include the building of any structure involving rock, sand, dirt, or other construction material. No discharge may occur unless a permit is obtained from the U.S. Army Corps of Engineers. Generally, the project proponent must agree to mitigate or have plans to mitigate environmental impacts caused by the project before a permit is issued. The U.S. Environmental Protection Agency has the authority to veto permits issued by the Corps for projects that have unacceptable adverse effects on municipal water supplies, fisheries, wildlife, or recreational areas.

Section 404 permits the issuance of a general permit on a State, regional, or nationwide basis for certain categories of activities that will cause only minimal environmental effects. Such activities are permitted without the need of an individual permit application. Installation of a stream gauging station along a river levee is one example of an activity which falls within a nationwide permit.

The Corps also administers a permitting program under Section 10 of the 1899 Rivers and Harbors Act. Section 10 generally requires a permit for obstructions to navigable water. The scope of the permit under Section 10 is narrower than under Section 404 since the term "navigable waters" is more limited than "waters of the United States."

The majority of water development projects must comply with Section 404, Section 10, or both. For example, proposed facilities such as Los Banos Grandes and Phase II of the Coastal Branch for the SWP and Los Vaqueros for the Contra Costa Water District, as well as activities within Delta channels, are subject to 404 jurisdiction and regulation.

Public Interest Terms and Conditions. The Water Code authorizes the SWRCB to impose public interest terms and conditions to conserve the public interest, specifically the consideration of instream beneficial uses, when it issues permits to appropriate water. It also considers environmental impacts of approving water transfers under its jurisdiction. Frequently, it reserves jurisdiction to consider new instream uses and to modify permits accordingly. D-1485 fish and wildlife conditions that regulate CVP and SWP Delta operations were imposed under a reservation of SWRCB's jurisdiction.

Releases of Water for Fish. Fish and Game Code Section 5937 provides protection to fisheries by requiring that the owner of any dam allow sufficient water at all times to pass through the dam to keep in good condition any fisheries that may be planted or exist below the dam. In *California Trout, Inc. v. the State Water Resources Control Board* (1989), the court determined that Fish and Game Code sections 5937 and 5946 require the SWRCB to modify the permits and licenses issued to the City of Los Angeles to appropriate water from the streams feeding Mono Lake to ensure sufficient water flows for fisheries purposes. In a subsequent case, the court of appeal ordered the Superior Court to set interim flow standards for the four streams feeding Mono Lake and from which the City diverts. The Alpine County Superior Court entered a preliminary injunction prohibiting Los Angeles from diverting water whenever the Mono Lake level falls below 6,377 feet.

Streambed Alteration Agreements. Fish and Game Code Sections 1601 and 1603 require that any governmental entity or private party altering a river, stream, or lake bed, bottom or channel enter into an agreement with the Department of Fish and Game. Where the project may substantially impact an existing fish or wildlife resource, DFG may require that the agreement include provisions designed to protect riparian habitat, fisheries, and wildlife. New water development projects and on-going maintenance activities are often subject to these sections.

Migratory Bird Treaty Act. This act implements various treaties for the protection of migratory birds and prohibits the "taking" (broadly defined) of birds protected by those treaties without a permit. The Secretary of the Interior is directed to determine conditions under which a taking may occur, and criminal penalties are provided for unlawful taking or transportation of birds. Liability imposed by this act was one of several factors leading to the decision to close the Kesterson Wildlife Refuge. (See the discussion of the San Joaquin Valley Drainage Program under *Management Programs* in this chapter.)

Environmental Review and Mitigation

Another set of environmental statutes compels governmental agencies and private individuals to document and consider environmental consequences of their actions. They define the procedures through which governmental agencies consider environmental factors in their decision-making process.

National Environmental Policy Act. NEPA directs federal agencies to prepare an environmental impact statement for all major federal actions which may have a significant effect on the human environment. It states that it is the goal of the federal government to use all practicable means, consistent with other considerations of national policy, to protect and enhance the quality of the environment. It is a procedural law requiring all federal agencies to consider the environmental impacts of their proposed actions during the planning and decision-making processes. The content of an EIS is very similar to that required by the California Environmental Quality Act for a State environmental impact report.

California Environmental Quality Act. CEQA, modeled after NEPA, requires California public agency decision makers to document and consider the environmental impacts of their actions. It requires an agency to identify ways to avoid or reduce environmental damage and to implement those measures where feasible. It also serves as a means to encourage public participation in the decision-making process. CEQA applies to all levels of California government, including the State, counties, cities, and local districts.

CEQA requires that a public agency carrying out a project with significant environmental effects prepare an environmental impact report. An EIR contains a description of the project; a discussion of the project's environmental impacts, mitigation measures, and alternatives; public comments; and the agency's responses to the comments. In other instances, a notice of exemption from the application of CEQA may also be appropriate.

NEPA does not generally require federal agencies to adopt mitigation measures or alternatives provided in the EIS. CEQA, on the other hand, does impose substantive duties on all California governmental agencies approving projects with significant environmental impacts to adopt feasible alternatives or mitigation measures that substantially lessen these impacts, unless there are overriding reasons why they cannot. When a project is subject to both CEQA and NEPA, both laws encourage the agencies to cooperate in planning the project and to prepare joint environmental documents.

Fish and Wildlife Coordination Act. The Fish and Wildlife Coordination Act and related acts express the policy of Congress to protect the quality of the aquatic environment as it affects the conservation, improvement, and enjoyment of fish and wildlife resources. Under this act, any federal agency that proposes to control or modify any body of water, or to issue a permit allowing control or modification of a body of water, must first consult with the U.S. Fish and Wildlife Service and State Fish and Game officials. This requires coordination early in the project planning and environmental review processes.

Protection of Wild and Natural Areas

Water use and management are also limited by several statutes designed to set aside resources or areas to preserve their natural conditions. This precludes certain activities, including most water development projects, within the areas set aside.

Federal Wild and Scenic Rivers System. In 1968, Congress passed the National Wild and Scenic Rivers Act to preserve in their free-flowing condition rivers which possess "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values." The act also states: ". . . that the established national policy of dam and other construction at appropriate sections of rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes."

The act prohibits federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct and adverse effect on the values for which the river was designated. This restriction also applies to rivers designated for potential addition to the National Wild and Scenic Rivers System. California rivers included in the system include portions of the Middle Fork Feather, North Fork American, Tuolumne, Merced, Kings, North Fork Kern, South Fork Kern, Smith, Sisquoc, and Big Sur Rivers, and Sespe Creek (Figure 2-1). Also included in the system are most rivers protected under the State Wild and Scenic Rivers Act; these rivers were included in the national system upon California's petition on January 19, 1981. The West Walker and East Fork Carson rivers are not included in the federal system.

California Wild and Scenic Rivers System. In 1972, the California legislature passed the State Wild and Scenic Rivers Act, declaring that specified rivers possess extraordinary scenic, recreational, fishery, or wildlife values that should be preserved in a free-flowing state for the benefit of the people of California. It declared that such use of the rivers would be the highest and most beneficial use within the meaning of Article X, Section 2 of the California Constitution. The act prohibits construction of any dam, reservoir, diversion, or other water impoundment on a designated river. Diversions needed to supply domestic water to residents of counties through which the river flows may be authorized, if the Secretary of the Resources Agency determines that the diversion will not adversely affect the river's free-flowing character. The State system includes portions of the Klamath, Scott, Salmon, Trinity, Smith, Eel, Van Duzen, American, West Walker, and East Fork Carson rivers. While not technically a part of the system, similar protection also extends to portions of the McCloud River.

The major difference between the national and State acts is that if a river is designated wild and scenic under the State act, the Federal Energy Regulatory Commis-

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Figure 2-1. Wild and Scenic Rivers in California

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sion can still issue a license to build a dam on that river, thus overriding the state system. (See Federal Power Act discussion above.) This difference explains why national wild and scenic designation often is sought.

Wild Trout Streams. The California Fish and Game Code designates certain sections of streams and rivers as "wild trout waters." The Trout and Steelhead Conservation and Management Planning Act of 1979 directs the Department of Fish and Game to inventory all California trout streams and lakes and determine whether each should be managed as a wild trout fishery or involve the planting of trout. The objective of the legislation is to establish and maintain wild trout stocks in suitable waters of the State and establish angling regulations designed to maintain the wild trout fishery by natural reproduction. The legislature further directed that part of the wild trout program be devoted to developing catch and release fisheries. The Fish and Game Commission has designated 26 streams as "wild trout waters," and adopted a policy pursuant to Fish and Game Code Section 703 that "[a]ll necessary actions, consistent with state law, shall be taken to prevent adverse impact by land or water development projects on designated wild trout waters."

National Wilderness Act. The Wilderness Act sets up a system to protect federal land designated by Congress as a "wilderness area" and preserve it in its natural condition. Wilderness is defined as undeveloped federal land retaining its primeval character and influence without permanent improvements or human habitation. Commercial enterprise, permanent roads, motor vehicles, aircraft landings, motorized equipment, or construction of structures or installations are prohibited within designated wilderness areas.

Water Quality Protection

Another important consideration in water resource management is water quality. The State Water Resources Control Board plays a central role in both determining water rights and regulating water quality. Discussed below are key State and federal laws governing water quality.

Porter-Cologne Water Quality Control Act

This act is California's comprehensive water quality control law and is a complete regulatory program designed to protect water quality and beneficial uses of the State's water. The act requires the adoption of water quality control plans by the state's nine Regional Water Quality Control Boards for areas within their regions. These plans are subject to the approval of the State Water Resources Control Board, and ultimately the federal EPA. The plans are to be continually reviewed and updated.

The primary method of implementing the plans is to require each discharger of waste that could impact the waters of the State to meet formal waste discharge requirements. Anyone discharging waste or proposing to discharge waste into the State's water must file a "report of waste discharge" with the Regional Water Quality Control Board within whose jurisdiction the discharge lies. Dischargers are subject to a wide variety of administrative, civil, and criminal actions for failing to file a report. After the report is filed, the regional board may issue waste discharge requirements that set conditions on the discharge. The waste discharge requirements must be consistent with the water quality control plan for the body of water and protect the beneficial uses of the receiving waters. The regional boards also implement Section 402 of the federal Clean Water Act, which allows the State to issue a single discharge permit for the purposes of both State and federal law.

National Pollutant Discharge Elimination System

Section 402 of the Clean Water Act established a permit system known as the National Pollutant Discharge Elimination System to regulate point sources of discharges in navigable waters of the United States. The EPA was given the authority to implement the NPDES, although the act also authorizes states to implement the act in lieu of the EPA, provided the state has sufficient authority.

In 1972, the California Legislature passed a law amending the Porter–Cologne Act which gave California the authority and ability to operate the NPDES permits program. Before a permit may be issued, Section 401 of the Clean Water Act requires that the Regional Water Quality Control Board certify that the discharge will comply with applicable water quality standards. After making the certification, the regional board may issue the permit satisfying both State and federal law. The State Water Resources Control Board is currently reviewing the activities subject to nationwide permits to determine if they qualify for water quality certification.

In 1987, Section 402 was amended to require the regulation of storm water runoff under the NPDES, despite the fact that it comes from a large variety of sources which the EPA in the past claimed were too diffuse to be controlled. The EPA and the State Board have adopted some regulations and general permits for certain categories of storm water discharges, but regulations covering all sources have not yet been approved.

Drinking Water Quality

The Federal Safe Drinking Water Act, enacted in 1974 and significantly amended in 1986, directed the Environmental Protection Agency to set national standards for drinking water quality. It required the EPA to set maximum contaminant levels for a wide variety of contaminants by establishing maximum allowable concentrations in drinking water supplies. The local water suppliers were given the responsibility to monitor their public water supplies to assure that MCLs were not exceeded and report to the consumers if they were.

The 1986 amendments set a time table for the EPA to establish standards for specific contaminants and increased the range of contaminants local water suppliers

Point-Source Versus Nonpoint-Source Pollution

A permit system prohibiting point–source discharges of pollutants may not be effective as the sole method of implementing water quality control plans. The classic example of this occurs in the Sacramento–San Joaquin Delta where a major water quality problem is the intrusion of salt water from the San Francisco Bay. When flows from rivers feeding into the Delta are reduced, whether naturally or by upstream diversions, salt water from the bay intrudes into the Delta. High salinities can cause problems for agricultural, municipal and industrial diverters in the Delta; for fish, wildlife, and their habitat; and for water quality at the CVP and SWP pumps in the southern Delta.

The Porter–Cologne Water Quality Control Act requires SWRCB to "establish such water quality objectives. . . as in its judgment will ensure the reasonable protection of beneficial uses. . . ." Beneficial uses include domestic, municipal, agricultural and industrial supply; power generation; recreation, aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves. Establishing water quality objectives for the Delta and determining how to implement them is a major ongoing water management issue in California.

were required to monitor to include contaminants that did not yet have an MCL established. They also strengthened enforcement authority, required filtration and disinfection of surface supplies not adequately protected, banned future use of lead pipe and lead solder, and required the EPA to evaluate monitoring methods for deep-well injection waste-disposal sites. They included a wellhead protection program, a grant program for designating sole-source aquifers for special protection, and grant programs and technical and financial assistance to small systems and states.

In 1976, California enacted its own Safe Drinking Water Act requiring the State Department of Health Services to administer laws relating to drinking water regulation, including: setting and enforcing both federal and State drinking water standards, administering water quality testing programs, and administering permits for public water system operations. The federal Safe Drinking Water Act permits the State to enforce its own standards in lieu of the federal standards so long as they are at least as protective as the federal standards. Significant amendments to the State's act in 1989 incorporated the new federal safe drinking water act requirements into California law, gave DHS discretion to set more stringent MCLs, and recommended public health levels for contaminants. DHS was authorized to take the technical and economic feasibility of reducing contaminants into account in setting MCLs. The standards established by DHS are found in the California Code of Regulations, Title 22.

California voters have also passed a series of bond laws to finance grants and low-interest loans to local water suppliers to bring domestic water systems up to drinking water standards. These grant and loan programs are jointly administered by DWR and DHS Office of Public Drinking Water.

San Francisco Bay and the Sacramento-San Joaquin Delta

Any discussion of California water policy in the 1990s must include a discussion of issues involved in the Delta because almost all developing areas of law, as well as the CVP and SWP operations, are inextricably intertwined in this complex set of issues. A discussion of Delta issues can provide an interesting example of how a great deal of the institutional framework already discussed in this chapter interrelates. Delta issues include water quality, threatened and endangered species such as winter-run salmon and Delta smelt, water rights, the public trust doctrine, and operation of California's two major water projects.

State Water Project and Federal Central Valley Project

The California Central Valley Project Act was approved by the voters in a referendum in 1933, which authorized construction of the Central Valley Project. The State was unable to construct the project at that time because of the Great Depression; portions of the CVP were subsequently authorized and constructed by the United States. Other portions of it were constructed by the State after the Depression as part of the State Water Project, as authorized in 1960 under the Burns-Porter Act. Principal facilities of the State Water Project include Oroville Dam, Delta Facilities, the California Aqueduct, and North and South Bay Aqueducts. Principal facilities of the federal CVP include Shasta, Trinity, Folsom, Friant, Clair Engle, Whiskeytown, and New Melones dams, Delta facilities, and the Delta Mendota Canal. Joint SWP/CVP facilities include San Luis Reservoir and Canal and various Delta facilities. Specific laws authorizing construction of elements of both the State and federal projects are listed in Appendix A.

The SWRCB issued the first water rights permits to the USBR for operation of the CVP in 1958, and to DWR for operation of the SWP in 1967. Key features of these water rights permits were the ability to divert water from the Delta and send it west to the San

Francisco Bay area and south to San Joaquin Valley farms and Southern California urban areas. In these and all succeeding permits issued for the CVP and SWP, the SWRCB reserved jurisdiction to formulate or revise terms and conditions relative to salinity control, effect on vested rights, and fish and wildlife protection in the Sacramento-San Joaquin Delta. The Board has a dual role of both issuing water rights permits and regulating water quality.

Decision 1485

On April 29, 1976, the Board initiated proceedings leading to the adoption of Water Right Decision 1485 in 1978. Decision 1485 set forth conditions—including water quality standards, export limitations, and minimum flow rates—for SWP and CVP operations in the Delta and superseded all previous water rights decisions for the SWP and CVP operations in the Delta. Among beneficial uses to be protected by the decision were (1) municipal and industrial water supply, (2) agriculture, and (3) fish and wildlife. Decision 1485 established flow and water quality standards to protect these beneficial uses.

In formulating Decision 1485, the SWRCB asserted that Delta water quality should be at least as good as it would have been if the SWP and CVP had not been constructed. In other words, both the SWP and the CVP were to be operated to meet "without project" conditions. Decision 1485 standards included different levels of protection to reflect variations in hydrologic conditions during different types of water years.

To help implement these water quality standards, Decision 1485 also mandated an extensive monitoring program. It also called for special studies to provide critical data about major concerns in the Delta and Suisun Marsh for which information was insufficient. Decision 1485 included water quality standards for Suisun Marsh, as well as for the Delta, requiring DWR and the USBR to develop a plan for the marsh that would ensure meeting long-term standards for full protection by October 1984, later extended to October 1988.

Recognizing that the complexities of project operations and water quality conditions would change over time, the SWRCB also specified that the Delta water right hearings would be reopened within ten years of the date of adoption of Decision 1485, depending upon changing conditions in the Bay-Delta region and the availability of new evidence on beneficial uses of water.

Racanelli Decision

Lawsuits by various interests challenged Decision 1485, and the decision was overturned by the trial court in 1984. Unlike its predecessor, D-1379, whose standards had been judicially stayed, D-1485 remained in effect. In 1986, the appellate court in the *Racanelli Decision* (named after Judge Racanelli who wrote the opinion) broadly interpreted the SWRCB's authority and obligation to establish water quality objectives and its authority to set water rights permit terms and conditions that provide reasonable protection of beneficial uses of Delta water and of San Francisco Bay. The court stated that SWRCB needed to separate its water quality planning and water rights functions. SWRCB needs to maintain a "global perspective" in identifying beneficial uses to be protected (not limited to water rights) and in allocating responsibility for implementing water quality objectives (not just to the SWP and CVP, nor only through the Board's own water rights processes). The court recognized the SWRCB's authority to look to all water rights holders to implement water quality standards and advised the Board to consider the effects of all Delta and upstream water users in setting and implementing water quality standards in the Delta, as well as those of the SWP and the CVP.

Coordinated Operation Agreement

Later in 1986, DWR and the USBR signed the landmark Coordinated Operation Agreement obligating the CVP and the SWP to coordinate their operations to meet Decision 1485 standards, in order to address overlapping concerns and interests in the Sacramento-San Joaquin Delta. The agreement authorizes the Secretary of the Interior to operate the CVP in conjunction with the SWP to meet State water quality standards for the San Francisco Bay and the Delta (unless the Secretary determines such operation to be inconsistent with Congressional directives), and provides a formula for sharing the obligation to provide water to meet water quality standards and other in-basin uses. It sets forth the basis upon which the CVP and the SWP will be operated to ensure that each project receives an equitable share of the Central Valley's available water and guarantees that the two systems will operate more efficiently during periods of drought than they would were they operated independently of one another. Under the COA, the USBR also agreed to meet future water quality standards established by the SWRCB unless the Secretary of the Interior determines that the standards are inconsistent with Congressional intent.

SWRCB Bay-Delta Proceedings

Hearings to adopt a water quality control plan and water rights decision for the Bay-Delta estuary began in July 1987. Their purpose was to develop a San Francisco Bay/Sacramento-San Joaquin Delta water quality control plan and to consider public interest issues related to Delta water rights, including implementation of water quality objectives. During the first phase of the proceedings, State and federal agencies, including DWR, public interest groups, and agricultural and urban water purveyors provided many expert witnesses to testify on a variety of issues pertaining to the reasonable and beneficial uses of the estuary's water. This phase took place over six months, and generated volumes of transcripts and exhibits.

The SWRCB released a draft Water Quality Control Plan for Salinity and Pollutant Policy Document in November 1988. However, the draft water quality control plan, a significant departure from the 1978 plan, generated considerable controversy throughout the State. The Pollutant Policy Document was subsequently adopted in June 1990.

In January 1989, the SWRCB decided to significantly amend the draft plan and redesign the hearing process. The water quality phase was to continue, an additional scoping phase would follow, and issues related to flow were to be addressed in the final water rights phase. Concurrently, DWR and other agencies offered to hold a series of workshops to address the technical concerns raised by the draft plan. These workshops were open to the public and benefited all parties involved by facilitating a thorough discussion of technical issues. After many workshops and revisions to the water quality control plan, the SWRCB adopted a final plan in May 1991. The federal EPA rejected this plan in September 1991.

With the adoption of the Water Quality Control Plan, the SWRCB began the EIR scoping phase and held several workshops during 1991 to receive testimony regarding planning activities, facilities development, negotiated settlements, and flow objectives. The goal was to adopt an EIR and a water right decision by the end of 1992.

In response to the Governor's April 1992 water policy statement, SWRCB decided to proceed with a process to establish interim Bay-Delta standards to provide immediate protection for fish and wildlife. Water right hearings were conducted from July through August 1992, and draft interim standards (proposed Water Right Decision 1630) were released for public review in December 1992. Concurrently, under the broad authority of the Endangered Species Act, the federal regulatory process was proceeding toward development of Delta standards and upstream measures applicable to the CVP and SWP for the protection of the threatened winter-run chinook salmon. In February 1993, the National Marine Fisheries Service issued a long-term biological opinion governing operations of the CVP and SWP with Delta environmental regulations that in certain months were more restrictive than SWRCB's proposed measures. On March 1, 1993, the U.S. Fish and Wildlife Service officially listed the Delta smelt as a threatened species and shortly thereafter indicated that further restrictions of CVP and SWP operations would be required.

In April 1993, the Governor asked the SWRCB to withdraw its proposed Decision 1630 and instead, to focus efforts on establishing permanent standards for protection of the Delta since recent federal actions had effectively pre-empted State interim standards and provided interim protection for the Bay-Delta environment. On December 15, 1993, EPA announced its proposed standards for the estuary in place of SWRCB water quality standards EPA had rejected in 1991; USFWS proposed to list the Sacramento splittail as a threatened species; and NMFS announced its decision to change the status of winter-run salmon from threatened to endangered.

In April 1994, the SWRCB began a series of workshops to review Delta protection standards adopted in its 1991 Water Quality Control Plan for Salinity and to examine proposed federal EPA standards issued in December 1993. These processes seek to involve both SWRCB and EPA and are intended to establish a mutually acceptable draft SWRCB Delta regulatory plan scheduled for release in December 1994. The plan will be developed in accordance with the Triennial Review requirements of the Clean Water Act.

The California Water Policy Council, created to coordinate activities related to the State's long-term water policy, and the Federal Ecosystem Directorate (sometimes referred to as "Club Fed"), comprising representatives from the EPA, NMFS, USFWS, and the USBR, have developed and signed a framework agreement for the Bay-Delta Estuary. The agreement provides for improved coordination and communication among State and federal agencies with resource management responsibilities in the estuary. It covers the water quality standards setting process; coordinates water supply project operations with requirements of water quality standards, endangered species laws, and the Central Valley Project Improvement Act; and provides for cooperation in planning and developing long-term solutions to the problems affecting the estuary's major public values.

Coordination of State-federal resource management and long-range planning in the Bay-Delta Estuary is necessary to promote regulatory consistency and stability and to address the estuary's environmental problems in a manner that minimizes the costs to the State in water for urban and agricultural uses and in dollars.

Fish Protection Agreement

To mitigate fish losses at Delta export facilities, both the SWP and the CVP have entered into agreements with DFG. The SWP's Harvey O. Banks Delta Pumping Plant lies at the head of the California Aqueduct near the City of Tracy. When the plant was initially constructed, seven of the eleven pumping units planned were installed. The remaining four units were only recently installed to provide more operational flexibility.

During the environmental review process for installation of the remaining four pumps, DFG and DWR began negotiating an agreement for the preservation of fish potentially affected by the operation of the pumps. A unique aspect in the development of this agreement was the assistance provided by an advisory group made up of representatives from United Anglers, the Pacific Coast Federation of Fishermen's Associations, the Planning and Conservation League, and the State Water Contractors.

The Fish Protection Agreement was signed by the directors of the two departments in December 1986 and identifies the steps needed to offset adverse fishery impacts of the Banks Pumping Plant. It sets up a procedure to calculate direct fishery losses annually and requires DWR to pay for mitigation projects that would offset the losses. Losses of striped bass, chinook salmon, and steelhead are to be mitigated first. Mitigation of other species is to follow as impacts are identified and appropriate mitigation measures found. In recognition of the fact that direct losses today would probably be greater if fish populations had not been depleted by past operations, DWR also provided $15 million to initiate a program to increase the probability of quickly demonstrated results.

Suisun Marsh Preservation Agreement

Decision 1485 ordered USBR and DWR to develop a plan to protect the Suisun Marsh. The Suisun Marsh consists of a 55,000-acre managed wetland area in southern Solano County, just beyond the confluence of the Sacramento and San Joaquin rivers. One of the largest contiguous brackish water marshes in the United States, the Suisun Marsh is a unique and irreplaceable resource for migratory waterfowl. During the fall and winter, waterfowl traveling along the Pacific Flyway depend on the marsh as a feeding and resting area. An adequate supply of water is essential to maintain the health of the marsh. Upstream water diversions have reduced the Delta outflows that maintain the water quality required by the marsh ecosystem.

The Suisun Marsh Preservation and Restoration Act of 1979 authorized the Secretary of the Interior to enter into a Suisun Marsh cooperative agreement with the State of California to protect the marsh, and specified the federal share of costs for facilities. The plan was subsequently developed by DWR and other interested parties, and the initial facilities were completed in 1981. A salinity control structure on Montezuma Slough, consisting of radial gates and a boat lock, was completed in 1989. Negotiations among the Suisun Resource Conservation District, DFG, DWR, and USBR resulted in an agreement that would moderate the adverse effects of the SWP, CVP, and other upstream diversions on the water quality in the marsh. The agreement, along with a monitoring agreement and a mitigation agreement, approved in March 1987, describes proposed facilities to be constructed, a construction schedule, cost-sharing responsibilities of the State and federal governments, water quality standards, soil salinity, water quality monitoring, and purchase of land to mitigate the impacts of the Suisun Marsh facilities themselves.

A significant feature of the agreement is the schedule and sequence of construction for the facilities of the Plan of Protection which provides for test periods during which the effectiveness of the constructed facilities is to be evaluated. Assessments will then be made to determine whether additional facilities will be needed to meet the water quality standards of the agreement.

Surface Water Management

The following sections are brief descriptions of major statutes affecting surface water management in California.

Regional Water Projects

The statutes authorizing the major regional water projects in California are listed in Appendix A and include: the Hetch Hetchy Project, which supplies Tuolumne River water to the City and County of San Francisco and other Bay Area cities; the Colorado River Aqueduct, which supplies water from the Colorado River to serve several major urban areas in Southern California; the Los Angeles Aqueduct, which delivers water from the Owens Valley to the City of Los Angeles; and the Mokelumne River Aqueduct operated by the East Bay Municipal Utility District, which transports Sierra Nevada water from Pardee Reservoir to eastern San Francisco Bay cities. These projects are more fully described in Chapter 3, *Surface Water Supplies*.

Besides the major regional projects, there are over 40 different statutes under which local agencies may be organized and have, among their powers, the authority to distribute water. In addition, there are a number of special act districts, such as the Metropolitan Water District of Southern California. DWR Bulletin 155-94, *General Comparison of Water District Acts* (March 1989), presents a comparison of various water district acts in California.

Central Valley Project Improvement Act of 1992

On October 30, 1992, the President signed PL 102-575 into law, Title XXXIV of which is the Central Valley Project Improvement Act. The act is the first major piece of legislation to deal with the Central Valley Project since the Reclamation Reform Act of 1982, which made major reforms to acreage limitations and subsidies. The act makes significant changes to the management of this federal reclamation project, and creates a complex set of new programs and requirements applicable to the project. The USBR and the U.S. Fish and Wildlife Service, as directed by the Secretary of the Interior, are beginning to put into place the interim guidelines and procedures necessary to implement the act's provisions; however, it will take a number of years to complete all of the specified actions called for in the legislation.

The act covers five primary areas: limitations on new and renewed CVP contracts, water conservation and other water management actions, water transfers, fish and wildlife restoration actions, and establishment of an environmental restoration fund. With a few exceptions, new contracts for CVP water are prohibited until several requirements have been met, including completion of a programmatic Environmental Impact Statement analyzing direct and indirect impacts and benefits of implementing the act, including fish, wildlife, and habitat restoration and the potential renewal of the existing CVP water contracts.

Renewals of existing water service contracts are limited to a term of 25 years, and contracts can only be renewed on an interim basis until environmental documentation required by the act is completed. Specified water conservation provisions are to be added to the renewed, amended, and new water service contracts. Project water can now be transferred outside of the CVP service area on a willing seller/willing buyer basis, subject to approval of the transfer by the Secretary of the Interior and a number of other limiting conditions, some of which are discussed below in the *Water Transfers* section.

Implementation of environmental restoration measures is a major goal of the act, which specifically reauthorizes the CVP to establish fish and wildlife mitigation, protection, and restoration on a par with domestic and irrigation uses of water, and additionally places fish and wildlife enhancement on a par with hydropower generation. The act requires that 800,000 af annually of project yield be dedicated to general fish and wildlife, and habitat, purposes. It establishes a goal of doubling the natural production of anadromous fish in Central Valley rivers and streams (except for part of the San Joaquin River, which is treated separately) by 2002. The act further requires dedication of additional water for Trinity River instream flows, and for wetlands habitat areas in the Sacramento and San Joaquin valleys. The Secretary of the Interior is directed to undertake a number of physical measures to restore the fishery and habitat, such as construction of a temperature control device at Shasta Dam, and establishment of fish screening programs. The act requires that the Secretary enter into a cost-sharing agreement with the State of California for some of these mandated restoration measures. However, California's continuing budget difficulties make cost sharing problematic at this time. Funding for the restoration measures also comes from increased payments by CVP water and power users, from the federal treasury, and from a fee of $25 per acre-foot levied on water transferred to non-CVP municipal and industrial water users.

Transfer of the CVP

As early as 1952, in a report titled *Feasibility of State Ownership and Operation of the Central Valley Project of California*, the State recognized that State ownership of the CVP would be in its best interests. Transfer of the CVP to the State of California is one of the elements of the Governor's Long-Term Water Policy Framework for California. The policy recognizes that transfer of the CVP to California will optimize operational flexibility of the CVP and the SWP, and it could assure that California, rather than the federal government, has the authority for planning and allocating the State's water resources.

In March 1992, California's Governor and the federal Secretary of the Interior designated representatives to negotiate the transfer of control of the CVP to the State. Any such transfer will require: (1) authorizing legislation from Congress, (2) compliance with NEPA, CEQA, and other applicable State and federal laws, and (3) negotiation of detailed terms and conditions for the transfer. On December 14, 1992, the Governor and the Secretary of the Interior signed a Memorandum of Agreement outlining the process necessary to comply with NEPA and CEQA and for developing detailed terms and conditions. In 1993, the negotiations were stopped as other events affecting the CVP eclipsed this process.

Trends in Water Resource Management

Factors having major influence on water management and policy over the past six years have been the 1987-1992 drought, expanding water needs due to growth and increasing recognition of the need for instream water uses, endangered species considerations, and the increasing difficulty of developing new water supplies, due in large part to environmental restrictions. In response to these problems, water managers are paying added attention to using water transfers and emphasizing water conservation. More attention is also being given to solving water management problems on a regional basis.

Water Transfers

Many water resource managers view water transfers, with appropriate safeguards against adverse environmental and third-party impacts, as an important tool for solving some of California's water supply and allocation problems. In fact, water transfers have occurred in California since Gold Rush days. There are generally fewer environmental impacts associated with transfers than with construction of conventional projects, and although difficult to implement, transfers can be implemented more quickly and usually at less cost than construction of additional facilities.

Under existing law, holders of both pre-1914 and appropriative water rights can transfer water. Holders of pre-1914 appropriative rights may transfer water without seeking approval of SWRCB, provided no other legal user of water is injured. Holders of appropriative rights may transfer water, but SWRCB must approve any transfer requiring a change in terms and conditions of the water right permit or license, such as place of use, purpose of use, or point of diversion. Short-term (one year or less) tempo-

Central Valley Project Improvement Act of 1992, 1993 CVP Operations

The 1993-94 water year is the first year of dedicated water use for fish and wildlife under the CVPIA (Title 34 of Public Law 102-575). Operations for 1993 dedicated 800,000 acre-feet, of which up to 400,000 is for the benefit of the Delta smelt. The 1993 prescribed measures include the following:

Sacramento and American River Basins

- ❑ At least an 8,000-cubic-foot-per-second pulse flow from Keswick Dam for a five-day period in late April to assist downstream migration of juvenile fall-run chinook and help provide the pulse flow needed in the Delta for Delta smelt and striped bass.
- ❑ At least 4,000-cfs releases from Keswick Dam to the Sacramento River from October through March, and at least 1,750 cfs from Nimbus Dam to the American River from October through February. These are to eliminate flow fluctuations for the spawning, incubation, and rearing of fall-run and late fall-run chinook salmon and steelhead trout.
- ❑ Close the Delta Cross Channel gates during May to reduce entrainment of downstream migrating fall-run chinook salmon, striped bass eggs and larvae, and other Delta species.

Stanislaus and San Joaquin River Basins

- ❑ Two pulse flows from New Melones Reservoir of at least 1,500 cfs: (1) from April 24 to May 16 primarily to help move fall-run chinook salmon smolts downstream and past the Delta pumps, secondarily to benefit Delta smelt; and (2) from May 20 to June 2 primarily to aid Delta smelt, secondarily to benefit striped bass and fall-run chinook salmon.
- ❑ A pulse flow of 1,000 to 2,000 cfs below New Melones Reservoir for a 7- to 14-day period in fall 1993 to attract upstream migrating fall-run chinook salmon.
- ❑ A base flow release of at least 300 cfs from New Melones Reservoir to the Stanislaus River from October through March to improve spawning and rearing conditions for fall-run chinook salmon.
- ❑ A carryover of 100,000 to 115,000 acre-feet in New Melones Reservoir beyond spring of 1994 for improved water temperatures and as a contingency against drought.

The Delta

- ❑ No reverse flow in the western Delta in May and June, maximum reverse flow of 1,000 cfs in July, and maximum reverse flow of 2,000 cfs in August, December, and January, specifically to benefit Delta smelt.
- ❑ A springtime pulse flow of about 4,500 cfs on the San Joaquin River side of the Delta. (Stanislaus River pulses and releases from other tributaries described above should provide this flow.)
- ❑ A pulse flow of at least 18,000 cfs from about April 20 to May 4 in the Sacramento River side of the Delta at Freeport. (The Keswick Dam pulse described above should contribute greatly to this.) From April 20 through May 30, the 14-day running average flow at Freeport should be at least 13,000 cfs, with daily minimums of at least 9,000 cfs.
- ❑ Base flows at Chipps Island between 14,000 and 7,700 cfs from May through July.
- ❑ Pumping reductions to 1,500 cfs (federal and State combined) from April 26 to May 16 (during the San Joaquin River pulse flows). Increased pumping to 4,000 cfs for the remainder of May, and 5,000 cfs for the month of June.

The prescribed Delta measures will benefit outmigrating salmonids, striped bass, and Delta smelt, as well as other migratory and resident estuarine species.

rary transfers of water are exempt from compliance with CEQA, provided SWRCB approval is obtained. SWRCB must find no injury to any other legal users of the water and no unreasonable effect on fish, wildlife, or other instream beneficial uses. CEQA compliance is required for long-term transfers. (See Table 2-1 for further details.) Because of complex environmental problems in the Delta, SWRCB has announced it will not approve long-term transfers that increase Delta pumping until completion of an environmental evaluation of the cumulative impacts. In addition, permits from fish and wildlife agencies may be required if a proposed transfer will affect threatened or endangered species.

Water held pursuant to riparian rights is not transferable from place to place, although downstream appropriators may contract with riparians to leave water in a stream for potential downstream diversion. Water rights along an adjudicated stream that prior to the adjudication would have been considered riparian may be transferred subject to the terms of the court decree. Similarly, contractual water rights based upon an exchange for riparian rights may be transferable subject to the terms of the exchange contract. Transfers of ground water, and ground water substitution arrangements whereby ground water is pumped as a substitute for transferred surface water, may be, in some cases, subject to statutory restrictions designed to protect ground water basins against long-term overdraft and to preserve local control of ground water management. Under Water Code Section 1707, SWRCB can authorize conversion of any existing water right into an "instream appropriation" to benefit fish, wildlife, or other instream beneficial use. The potential of this new code section is just beginning to be explored. If the

Table 2-1. California Water Code Requirements for Water Transfers

Transfer Type	*Water Code Section*	*Requirements*	*Environmental Actions*	*Comments*
Temporary Urgency Change (one year or less)	1435	1. Urgent need 2. No injury to vested rights 3. No unreasonable effect on fish and wildlife 4. Use in public interest 5. Show diligence in seeking the permit or long-term change	Normal CEQA process	1. Petition must be filed with SWRCB 2. Change good for up to 180 days 3. Can be renewed 4. Board notice and action
Temporary Change for Transfer (one year or less)	1725-1732	1. If applicable, petitioner must have been diligent in petitioning for a permanent change 2. Involves only water consumptively used or stored 3. No injury to vested rights 4. No unreasonable effect on fish or wildlife	Exempt from CEQA	1. Permittee notifies SWRCB of proposed change 2. SWRCB must make findings 3. Hearing may be required 4. Effective 5 days after SWRCB approval 5. Good for 1 year or less
Long-term Transfer (more than one year)	1735	1. No injury to vested rights 2. No unreasonable effect on fish or wildlife	Normal CEQA process	1. Petition must be filed with SWRCB 2. SWRCB provides notice and opportunity for hearing 3. Good for any period in excess of 1 year

parties to a transfer intend to use facilities belonging to the SWP, CVP, or other entity for transporting the water, permission must be sought from the owner of the facility.

Water obtained pursuant to a water supply contract is also potentially transferable. However, most water supply contracts require the consent of the entity delivering the water. Almost all types of water rights can also be transferred in California, but typical transfers are structured so that water is transferred, while the original holder retains the water right. Several statutes provide that transfers of water do not impair or cause forfeiture of water rights.

As a result of conditions in California during the 1987–92 drought, transfers of water between suppliers or users who could temporarily reduce their usage to areas with water shortages have become more prevalent. Some of these transfers have been within the context of a State Drought Water Bank first created by Governor Wilson in 1991 and administered by DWR. The water bank was designed to move water from areas of greatest availability to areas of greatest need. There were three sources of water for the 1991 State Drought Water Bank: temporary surplus in reservoirs, surface supplies freed up by the use of ground water, and surface supplies freed up by fallowing agricultural lands. The 1992 State Drought Water Bank did not purchase surface supplies freed by fallowing of agricultural lands. Transfers of water outside the State–sponsored Water Bank have also become more prevalent, and many of these transfers involve DWR because they require conveyance of the transferred water through SWP facilities.

In 1991, temporary changes to the law designed to facilitate the State Drought Water Bank were enacted. These changes were made permanent in 1992. The law now authorizes water suppliers (local public agencies and private water companies) to contract with water users to reduce or eliminate water use for a specified period of time, and to transfer the water to a State Drought Water Bank or other water suppliers and users. It also provides that water proposed for transfer need not be surplus to requirements within the supplier's service area and specifies that use for a transfer is a beneficial use. Substitution of ground water from an overdrafted ground water basin for transferred surface water is prohibited unless the water was previously recharged to the basin as part of a ground water banking program. The amount of water made available by land

Water Transfer Criteria

In his water policy statement of April 6, 1992, the Governor stated that the following five criteria must be met in developing a fair and effective water transfer policy.

- Water transfers must be voluntary, and they must result in transfers that are real, not paper water. Above all, water rights of sellers must not be impaired.
- Water transfers must not harm fish and wildlife resources or their habitats.
- There needs to be assurances that transfers will not cause overdraft or degradation of ground water basins.
- Entities receiving transferred water should be required to show that they are making efficient use of existing water supplies, including carrying out urban Best Management Practices or agricultural Efficient Water Management Practices.
- Water districts and agencies that hold water rights or contracts to transferred water should have a strong role in deciding how transfers are carried out. Impacts on the fiscal integrity of the districts and on the economies of small agricultural communities must be considered.

fallowing is limited to 20 percent of the amount applied or stored by the water supplier unless the supplier approves a larger amount at a hearing.

Although these changes do much to facilitate water transfers by water suppliers, they do not address the issue of "user-initiated transfers" where the water user is not the holder of the water right, but has a contractual entitlement to water from the water supplier. There is much interest in developing legislation acceptable to suppliers, users, and potential buyers, whereby users can initiate transfers subject to reasonable terms and conditions imposed by suppliers to protect their legitimate interests and those of other water users.

The Central Valley Project Improvement Act of 1992 also contains provisions intended to increase the use of water transfers by providing that all individuals and districts receiving CVP water (including that under water right settlement and exchange contracts) may transfer it to any other entity for any project or purpose recognized as a beneficial use under State law. The Secretary of the Interior must approve all transfers. The affected district must approve any transfer involving over 20 percent of the CVP water subject to long-term contract with the district. Section 3405 (a) (1) also sets forth a number of conditions on the transfers, including conditions designed to protect the CVP's ability to deliver contractually obligated water or meet fish and wildlife obligations because of limitations in conveyance or pumping capacity. The conditions also require transfers to be consistent with State law, including CEQA. Transfers are deemed to be a beneficial use by the transferor, and are only permitted if they will have no significant long-term adverse impact on ground water conditions within the transferor district, and will have no unreasonable impact on the water supply, operations, or financial conditions of the district.

Water Use Efficiency

Article X, Section 2 of the California Constitution prohibits the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water. It also declares that the conservation and use of water "shall be exercised with a view to the reasonable and beneficial use thereof in the public interest and for the public welfare." Although provisions and requirements of the Constitution are self executing, the Constitution states that the Legislature may enact statutes in furtherance of its policy. Water Code Section 275 directs the Department of Water Resources and the State Water Resources Control Board to "take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste or unreasonable use of water." SWRCB's Water Right Decision 1600, directing the Imperial Irrigation District to adopt a water conservation plan, is an example of an action brought under Article X, Section 2. The board's authority to order preparation of such a plan was upheld in 1990 by the courts in *Imperial Irrigation District v. State Water Resources Control Board.*

Urban Water Management Planning Act. Since 1985, this act has required urban water suppliers serving more than 3,000 customers or more than 3,000 acre-feet per year to prepare and modify urban water conservation plans. The act authorizes the supplier to implement the water conservation program. The plans must contain a number of specified elements, including: estimates of water use; identification of existing conservation measures; identification of alternative conservation measures; a schedule of implementation of actions proposed by the plan; and, identification of the frequency and magnitude of water shortages. In 1991, the act was amended in response to the drought to require water suppliers to estimate water supplies available at the end of one, two, and three years, and to develop contingency plans for severe shortages.

Water Conservation in Landscaping Act. The Water Conservation in Landscaping Act required DWR, with the assistance of an advisory task force, to adopt a model water efficient landscape ordinance. The model ordinance was adopted in August 1992, and has been codified in Title 23 of the California Code of Regulations. It establishes methods of conserving water through water budgeting plans, plant use, efficient irrigation, auditing, and other methods.

Cities and counties were required to review the model ordinance and adopt a water efficient landscape ordinance by January 1, 1993, if they had not done so already. Alternatively, cities and counties could make a finding that such an ordinance is unnecessary due to climatic, geological, or topographic conditions, or water availability. If a city or county failed to adopt a water efficient landscape ordinance or make findings by January 31, 1993, the model ordinance became effective in that jurisdiction.

Agricultural Water Management Planning Act. Under this act, agricultural water suppliers supplying greater than 50,000 af of water were required to submit a report to DWR indicating whether there exists a significant opportunity to conserve water or reduce the quantity of highly saline or toxic drainage water through improved irrigation water management. The act provided that agricultural water suppliers, who indicated that they had an opportunity to conserve water or reduce the quantity of highly saline or toxic water, were to prepare a water management plan and submit it to DWR no later than December 31, 1991. The act provides that the contents of the water management plans include a discussion of the water conservation practices currently used and a determination of whether, through improved management practices, an opportunity exists for additional water conservation. DWR was required to review the plans and submit a report to the Legislature by January 1993. Currently, almost 60 information reports and plans have been submitted to DWR.

Agricultural Water Suppliers Efficient Management Practices Act. The Agricultural Water Suppliers Efficient Management Practices Act, adopted in 1990, requires that DWR establish an advisory task force to review efficient agricultural water management practices. DWR is required under the act to offer assistance to agricultural water suppliers seeking to improve the efficiency of water practices. Members of the Committee have been selected and are working on methods to promote efficient practices. At the request of the Governor, the committee is working on a Memorandum of Understanding to implement the practices. A subcommittee is meeting on a monthly basis to complete this task. The proposed EWMPs are listed in Chapter 7.

Agricultural Water Conservation and Management Act of 1992. This act gives any public agency that supplies water for agricultural use, authority to institute water conservation or efficient management programs. The programs can include irrigation management services, providing information about crop water use, providing irrigation consulting services, improving the supplier's delivery system, providing technical and financial assistance to farmers, encouraging conservation through pricing of water, and monitoring.

Urban Best Management Practices MOU. The Urban BMPs are being implemented under the auspices of the California Urban Water Conservation Council. This council consists of about 150 water agencies, environmental organizations, and other interested parties. The council is responsible for quantifying BMPs, reviewing exemptions requested by water agencies from certain BMPs, and evaluating potential BMPs. The BMPs and potential BMPs are discussed in Chapter 6, under *Urban Water Conservation.*

Water Recycling Act of 1991. This act makes legislative findings regarding the environmental benefits and public safety of using recycled water as a reliable and cost-effective method of helping to meet California's water supply needs. It sets a statewide goal to recycle 700,000 AF per year by the year 2000 and 1,000,000 AF by 2010.

Management Programs

Management programs are increasingly being used as an approach to solving complex sets of regional water management problems. Three management programs that have had some success in dealing with regional issues are discussed below. Both the Sacramento River Fishery and Riparian Habitat Restoration Plan and the Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley (San Joaquin Valley Drainage Program) have been completed and are currently being used in making decisions affecting those resources. As discussed below, the San Joaquin drainage program addresses significant agricultural drainage issues, and elements of the plan are being implemented under both the 1992 CVP reform legislation and state legislation, particularly in the areas of water marketing and transfers, land fallowing, and conservation efforts. The San Joaquin River Management Program is still in the process of developing a management plan as of the writing of this Bulletin, and it appears a similar approach may be used by the Bay-Delta Oversight Council appointed by the Governor to "fix the Delta" in accordance with his April 1992 Water Policy.

Sacramento River Fishery and Riparian Habitat Restoration. In 1986, State legislation was enacted calling for a management plan to protect, restore, and enhance the fish and riparian habitat and associated wildlife of the Upper Sacramento River. The plan was prepared by an advisory council working closely with an action team, both composed of people representing a wide range of federal, State, and local agencies and private interests concerned with promoting the renewed health of the upper Sacramento River system. It was prepared with a spirit of cooperation and consensus and was published in January 1989. In September 1989, Senate Concurrent Resolution No. 62 declared that it is the policy of the State to implement the actions recommended in the Upper Sacramento River Fisheries and Riparian Habitat Management Plan. The plan recommends 20 fishery improvement items, several of which are contained in the CVP Improvement Act. Some items such as gravel restoration and Mill and Clear Creeks' restoration are receiving attention from various agencies.

San Joaquin Valley Drainage Program. The San Joaquin Valley Drainage Program was a federal and State interagency program established in August 1984 by the Secretary of the Interior and the Governor of California to study agricultural drainage problems in the San Joaquin Valley. The study was, in large part, a response to drainage problems that came to a head with the discovery of deformities and deaths of aquatic birds at Kesterson National Wildlife Refuge in 1983 that were determined to be caused by selenium poisoning.

The San Joaquin Valley has had a long history of inadequate drainage disposal and accumulation of salts on agricultural land. With importation of water for agricultural irrigation by the CVP and SWP, the problems were exacerbated. The original CVP and SWP plans called for the construction of the San Luis drain, with an outfall in the western Delta, as a joint federal and State facility. The State declined to participate, but the USBR eventually built the initial portion of the drain, about 120 miles of collector drains, and the first phase of a reservoir (Kesterson) designed to temporarily retain drainage water.

The drain never reached the proposed outlet into the Delta because in the mid-1970s questions about the potential effects of untreated agricultural drainage water on the quality of water in the Delta and San Francisco Bay were raised. Around that time it was decided that Kesterson should be used to store and evaporate drainage water until the outlet to the Delta could be built. Once the deformities and deaths of aquatic birds were discovered, however, use of Kesterson was halted and the reservoir was eventually closed in 1988.

In September 1990, the San Joaquin Valley Drainage Program published its final report, *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*. The recommended plan was regional and provided a framework designed to permit the present level of agricultural development in the San Joaquin Valley to continue for a few years while protecting fish and wildlife and helping to restore their habitat to levels existing before direct impact by contaminated drainage water.

The major components of the plan included: (1) control of the source of contaminated water by reducing application of irrigation water; (2) reuse of drainage water on progressively more salt-tolerant plants; (3) use of an evaporation system with safeguards for wildlife; (4) retirement of land with shallow ground water, elevated selenium, and soils that are difficult to drain; (5) management of ground water by pumping water suitable for irrigation or wildlife habitat from deep within the aquifer in order to lower surface water tables; (6) limited discharges to the San Joaquin River that meet water quality objectives; (7) protection, restoration, and provision of substitute water supplies for fish and wildlife habitat and fresh water supplies for wetlands habitat; and (8) institutional changes such as tiered pricing, water marketing and transfers, improved delivery scheduling, and formation of regional drainage management organizations.

To facilitate carrying out the plan component involving land retirement, the Legislature in 1992 enacted the San Joaquin Valley Drainage Relief Act, which permits DWR to acquire land and manage it (or enter into agreements to have the land managed by DFG or nonprofit organizations) as upland habitat, wetlands, or riparian habitat. In order to make the program self-supporting, water conserved as a result of the retirement of land would be sold and the proceeds used to purchase and retire additional lands.

The act requires DWR to maximize the water available for environmental needs and permits local agencies to use up to one-third of the water conserved and not sold for environmental purposes. The act recognizes that taking land out of production may impact local economies and directs DWR to consider these effects in purchasing land. It also directs DWR to coordinate with both the USBR, which provides much of the water to these areas, and local water agencies. Finally, the act expresses legislative intent that water distributed under the program be deemed contributions to a water resources mitigation bank, if such a bank is established.

The Central Valley Project Improvement Act also contains provisions relating to the San Joaquin Valley Drainage Program's plan. Section 3405 (e) establishes an office charged with developing criteria for and evaluating the adequacy of CVP contractors' water conservation plans. The office is required to give recognition to the final report of the San Joaquin Valley Drainage Program, among other things, in developing the criteria. Section 3406(b)(3) requires the Secretary of the Interior to implement a program to develop supplemental environmental water in conformance with the plan to double anadromous fisheries and the waterfowl habitat measures. "[T]emporary and permanent land fallowing, including purchase, lease, and option of water, water rights and associated agricultural land" are specifically mentioned as methods of developing the

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additional environmental water. Section 3408(h) specifically authorizes the Secretary of the Interior to purchase land to retire from irrigation if it would assist in water conservation or improve agricultural drainage or waste water problems. Once again the San Joaquin Valley Drainage Program report was specifically referred to. Finally, Section 3408(j) requires the USBR to develop a plan to replace water supplies for those used for fish and wildlife purposes within 15 years through a variety of means, including the purchase and idling of agricultural land.

San Joaquin River Management Program. In 1990, California legislation created a program "...to provide for the orderly development and management of water resources of the San Joaquin River system to accomplish compatible improvements of the system for flood protection, water supply, water quality, and recreation, and for the protection, restoration and enhancement of fish and wildlife." It created an Advisory Council and Action Team with members representing a wide range of State and local governmental, private, environmental, and other interests. The members meet on a regular basis. Their meetings formally began in November 1990 and are open to the public. Their objectives are to identify and describe issues and problems, establish a series of priority actions, identify proposed funding sources, and facilitate coordinated actions in the area. They are required to submit an annual report to the Legislature.

Interstate Water Resource Management

Colorado River

The Colorado River provides a primary source of supply for the South Coast and Colorado River regions. In addition to California, the states of Arizona, Nevada, Wyoming, Colorado, New Mexico, and Utah, and the Republic of Mexico, all use water from the Colorado River. In 1922, the seven states entered into an interstate compact which includes a provision for the equitable division and apportionment of the use of the waters of the Colorado River system. The Boulder Canyon Project Act of 1928 provided, among other things, for the construction of works to protect and develop the Colorado River Basin by the Department of Interior.

In the California Limitation Act of 1929, the State Legislature limited California's use of Colorado River water in response to requirements of the Boulder Canyon Project Act. Priorities within California were listed in a Seven Party Agreement of 1931. The United States-Mexico water treaty; signed in 1944, obligates the U.S. to deliver 1.5 maf per year to Mexico (up to 1.7 maf in surplus years). The U.S. Supreme Court Decree in *Arizona v. California*, 1964, established several additional dimensions to the apportionment of Colorado River water, including apportionments to the lower basin states—Arizona, Nevada, and California. In 1968, the Colorado River Basin Project Act authorized the Central Arizona Project and specified how water would be allocated to the lower basin states in years of insufficient runoff in the main stream (river) to satisfy the specified consumptive use of 7.5 maf. The act provided that California allocations of 4.4 maf have priority over allocations to the Central Arizona Project.

The Colorado River Board of California is the state agency with statutory responsibility to represent and protect the interests of California, its agencies, and its citizens concerning the water and power resources of the Colorado River system.

Truckee-Carson-Pyramid Lake Water Rights Settlement Act of 1991

Throughout the 1950s and 1960s interstate disputes over the waters of Lake Tahoe and the Truckee, Carson, and Walker rivers led the states of California and Nevada to negotiate an interstate compact equitably apportioning these waters. The

California-Nevada Interstate Compact was adopted by the two states in 1968 and ratified by their legislatures. Efforts of the two states to have the California-Nevada Interstate Compact approved by Congress were unsuccessful. Although numerous consent bills were introduced in Congress from 1971 to 1986, consent was never forthcoming. After 1986, the two states gave up trying to obtain congressional consent to the Compact.

The states did not give up other Congressional action. A new round of negotiations among the states, the federal government, the Pyramid Lake Paiute Tribe of Indians, and other interested parties led to the federal Truckee-Carson-Pyramid Lake Water Rights Settlement Act. Section 204 of this act specifies an apportionment of Lake Tahoe and the Truckee and Carson rivers between California and Nevada. It is the first Congressional apportionment since the Boulder Canyon Project Act of 1928. The act also addresses a number of other issues, including settlement of certain water supply disputes among the Pyramid Lake Tribe and other users of the Truckee and Carson rivers. The act also addresses a number of environmental issues, including recovery of Pyramid Lake fish species listed under the federal Endangered Species Act and protection and restoration of Lahontan Valley wetlands. Many of the act's provisions, including the interstate apportionment, will not become effective until a number of conditions are met, including dismissal of certain lawsuits and the negotiation of an operating agreement for the Truckee River between the United States, the two states, the Tribe, the Sierra-Pacific Power Company, and other parties.

For further information on the history of the Truckee River water rights disputes, and how they are addressed by the Settlement Act, see DWR's *June 1991 Truckee River Atlas*, and the December 1991 *Carson River Atlas*.

Klamath Project

Interstate aspects of the shared upper Klamath River and Lost River basins are addressed through the Klamath River Basin Compact. Negotiated by the states of Oregon and California, approved by their respective Legislatures, and consented to by the U.S. Congress in 1957, the compact is to (1) facilitate orderly development and use of water, and (2) further cooperation between the states in the equitable sharing of water resources. The compact is administered by the Klamath River Compact Commission, which is chaired by a federal representative appointed by the President. The commission provides a forum for communication between the various interests concerned with water resources in the upper Klamath River Basin. Its recent activities have focused on water delivery reductions caused by the drought and operating restrictions to protect two species of endangered sucker fish. Other pressing issues are water supplies for wildlife refuges and upper basin impacts on anadromous fisheries in the lower Klamath River.

Silverwood Lake stores and regulates State Water Project supplies and provides water-related recreation. Located on the west fork of the Mojave River in San Bernardino County, the reservoir stores up to 78,000 acre-feet behind a 236-foot-high dam.

Chapter 3

Surface Water Supplies

California has a wide range of climates due, in part, to its mountain ranges, which influence weather patterns and cause more precipitation on the western sides of the ranges than on the eastern sides. Average statewide precipitation is about 23 inches and most of it, about 60 percent, is used by native vegetation or lost by evaporation. Estimated average annual runoff amounts to about 71 million acre-feet. Not all of this runoff can be developed for urban or agricultural use. Much of it maintains healthy ecosystems in California's rivers and estuarine systems. Available surface water supply totals 78 maf when out-of-state supplies from the Colorado and Klamath rivers are added.

Uneven distribution of water resources is part of the State's geography. Roughly 75 percent of the natural runoff occurs north of Sacramento; about 75 percent of the net water demand is south of Sacramento. Almost 29 maf, or 40 percent of California's surface water supply, originates in the North Coast Region. The largest urban water use is in the South Coast Region where roughly half of California's population resides, and the largest agricultural water use is in the San Joaquin River and Tulare Lake regions where fertile soils, a long, dry growing season, and water availability have combined to make this area one of the most agriculturally productive areas in the world. For example, Fresno County is the most productive county in the United States in terms of agricultural output measured in dollars. The largest environmental water use is in the North Coast Region where average annual dedicated natural flow in wild and scenic rivers amounts to 18 maf. Figure 3-1 shows the disposition of average annual water supplies.

Figure 3-1. Disposition of Average Annual Water Supply

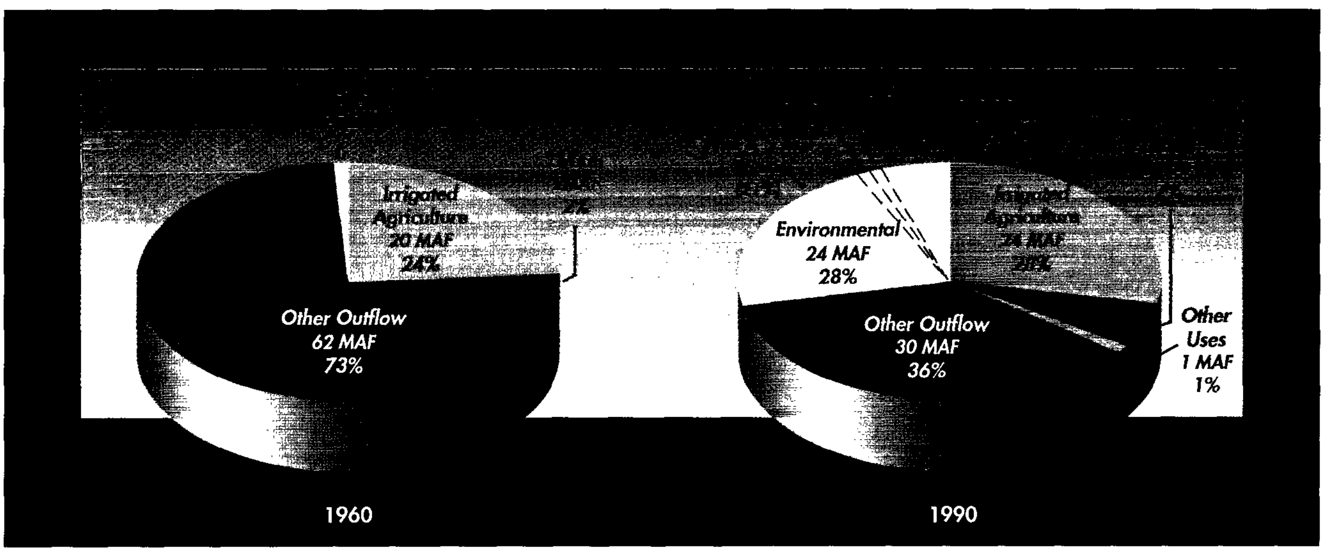

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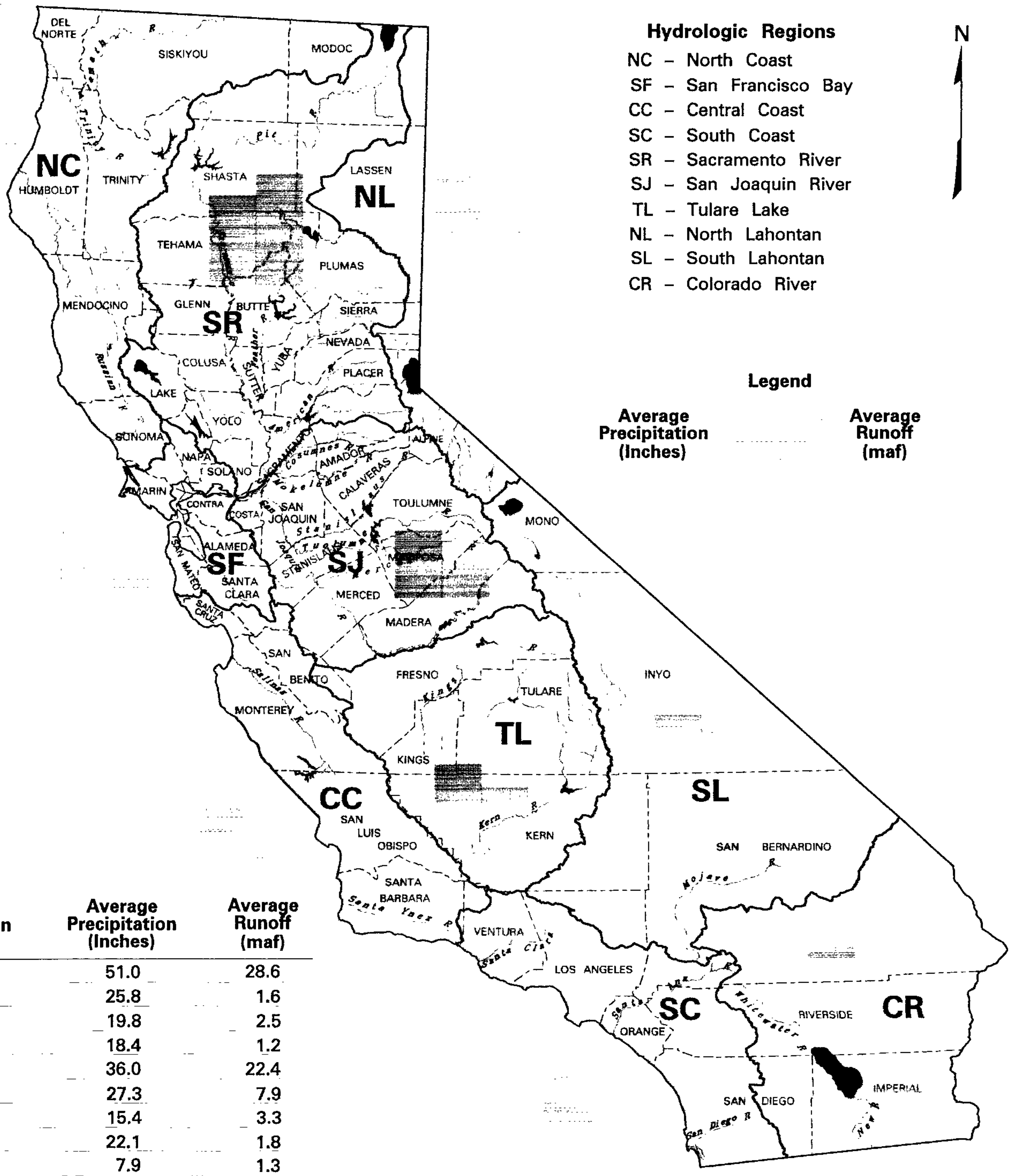
Figure 3-2. Distribution of Average Annual Precipitation and Runoff



Region	Average Precipitation (Inches)	Average Runoff (maf)
NC	51.0	28.6
SF	25.8	1.6
CC	19.8	2.5
SC	18.4	1.2
SR	36.0	22.4
SJ	27.3	7.9
TL	15.4	3.3
NL	22.1	1.8
SL	7.9	1.3
CR	5.5	0.2
Entire State	22.9	70.8

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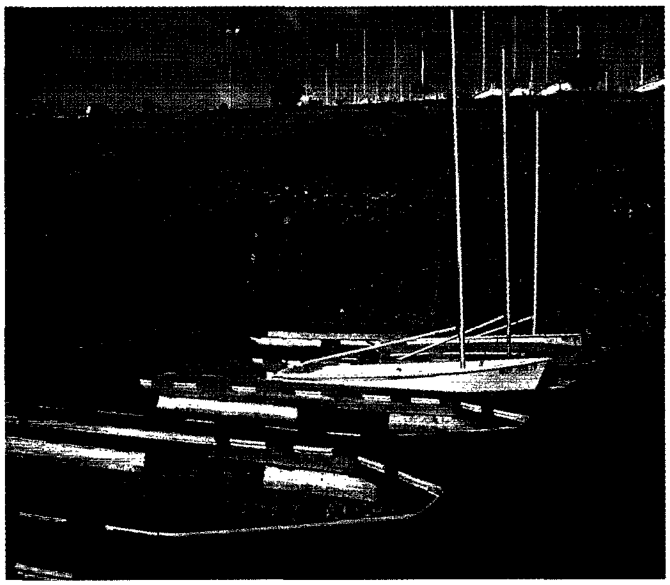
Droughts in California

Average runoff amounts are of some interest, but most of California's water development has been dictated by the extremes of droughts and floods. For example, the average yearly statewide runoff of 71 million acre-feet includes the all-time annual low of 15 maf in 1977 and the all-time high, exceeding 135 maf, in 1983. (Figure 3-2 shows the distribution of average annual precipitation and runoff.) Stable and reliable supplies are required to sustain agricultural and urban economies, whereas environmental water needs vary with the natural hydrologic cycle.



The 1987-92 drought lowered reservoir levels throughout California. These docks at Folsom Lake hit bottom during the drought. Folsom Dam usually stores over one million acre-feet.

The records of precipitation and runoff show that extremely dry periods frequently last several years. The seven-year drought of 1928-34 established the criteria commonly used to plan storage capacity or water yield of large Northern California reservoirs. From 1928 through 1937, the runoff was below average for ten straight years. Many reservoirs built since that time were sized to maintain a certain level of planned deliveries, or reliability, should there be a repeat of the 1928-34 dry period. The last 20 years have seen new record dry periods for one year (1977), two years (1976 through 1977), three years (1990 through 1992), and six years (1987 through 1992).

The Sacramento River Index is used both as a yardstick of Northern California water supply and in determining Delta water quality and flow criteria to be met by the federal Central Valley Project and the State Water Project. It classifies the runoff during a water year into five categories, ranging from critical (the driest) up to wet. Figure 3-3 shows the record of runoff for the index since 1906. The index is based on Water Right Decision 1485 and is the sum of unimpaired runoff in the Sacramento River (above Bend Bridge near Red Bluff), Feather River inflow to Oroville, Yuba River at Smartville, and American River inflow to Folsom. (*Unimpaired runoff* is the natural production of a stream unaltered by water diversions, storage, exports, or imports.) The major dry periods of this century include the 1929-34 dry period, the severe two-year drought of 1976-77, and the recent drought, in which five of the six years were classified as critical. The average of 18.4 maf shown on the chart is the currently used 50-year average; the average runoff for the entire 1906-93 period is slightly lower, about 17.8 maf.

The recent six-year drought is comparable to the 1929-34 sequence of dry years. Statewide precipitation from 1987-1992 was about 75 percent of average and annual streamflow was only about half of average. This drought was not quite the worst on record for the Sacramento Basin. Runoff in 1987-1992 was about 54 percent of average, about 1 percent more than the average during 1929-1934. Across the central part of the State, however, the recent drought was more severe than 1929-1934. The drought periods for Sacramento River Index runoff and for the San Joaquin River

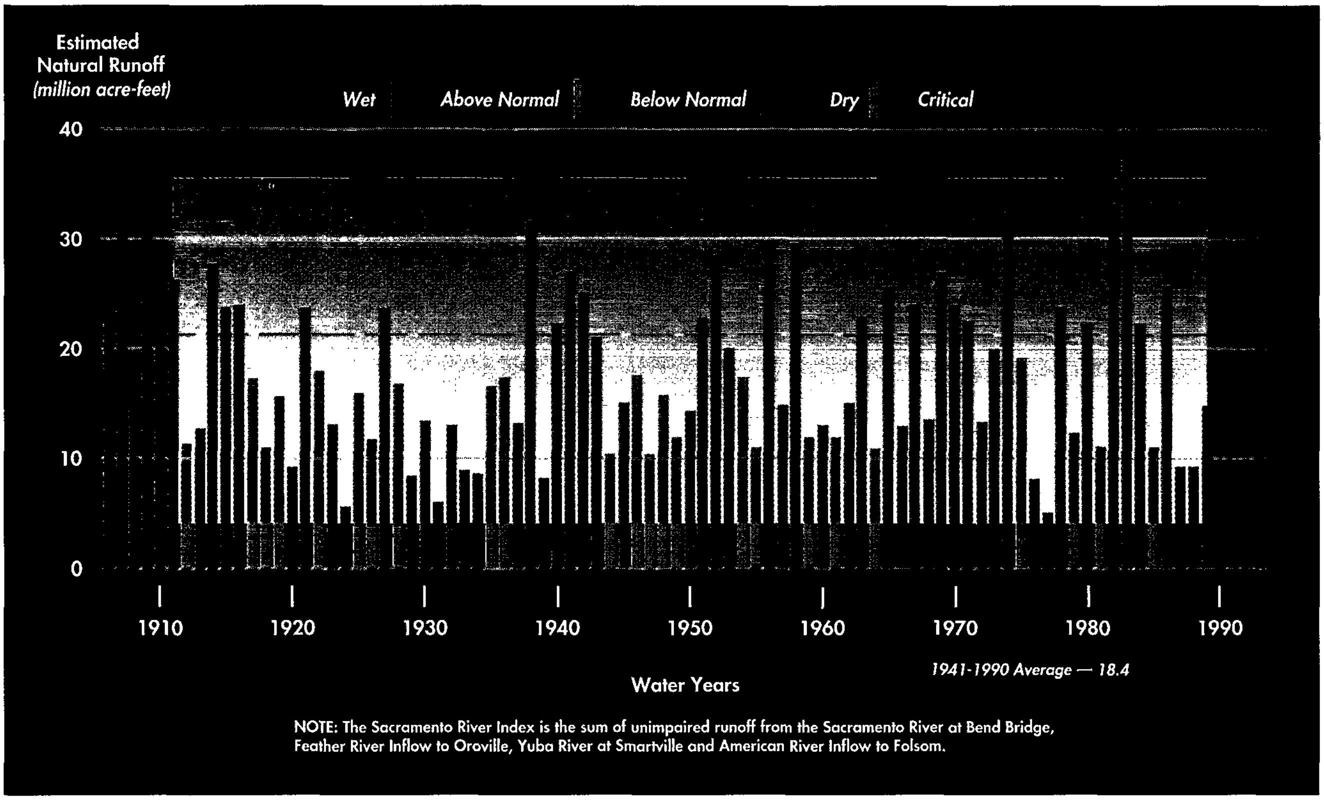
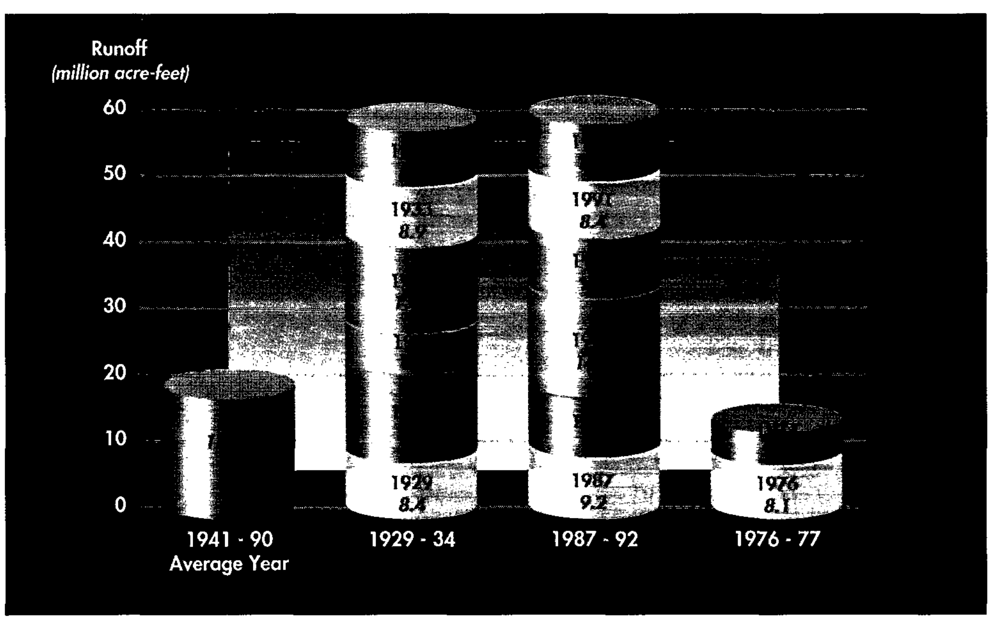


Figure 3–3. The Sacramento River Index Since 1906

Index runoff (the sum of the unimpaired runoff in the San Joaquin River at Friant, and the Stanislaus, Tuolumne, and Merced Rivers) are shown in Figures 3-4 and 3-5. The extended 1929–34 drought was softened somewhat in the southern Sierra Nevada by an above-average water year in 1932. The recent drought, although varying somewhat from year to year, was an unrelieved string of six critical years in the southern Sierra Nevada.

Figure 3-4. Comparison of Droughts Sacramento River Index



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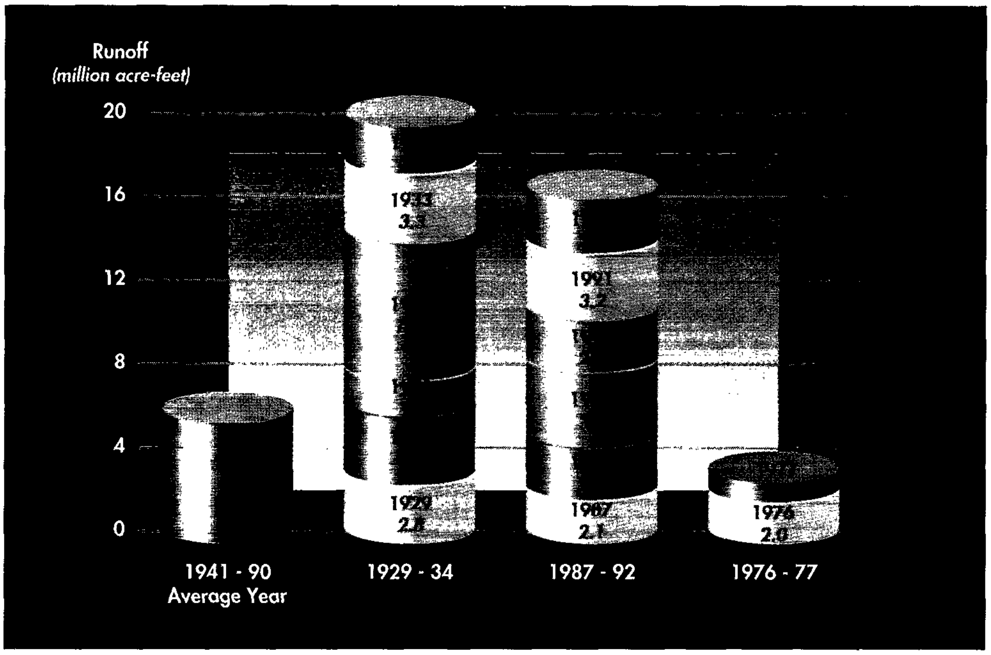

Figure 3-5. Comparison of Droughts San Joaquin River Index

In fall 1992, the storage in California's major reservoirs was somewhat under 12 maf, compared to a November 1 average of 21.4 maf. This was the lowest end–of–water–year storage level of the recent drought but was more than in 1977, when November 1 storage was only 7.6 maf.

Length and Frequency of Droughts

Each drought is different. In 1986, a tree-ring study reconstructed 420 years of Sacramento River runoff. The study was conducted for DWR by the Laboratory of Tree–Ring Research of the University of Arizona. The reconstruction suggests that the 1928–34 drought was the worst since 1560. (Water year 1928 was near normal, but its dry spring led into a series of six dry or critical water years.) Table 3–1 was excerpted from the reconstruction. It shows other dry periods with consecutive years of runoff less than 15.7 maf (the historical median) lasting at least three years, prior to 1900, for the reconstructed Sacramento River Index. Also shown are the measured droughts since 1900.

The record reconstructed from the tree-ring study does not always match the record of measured runoff, so the weight to be given to the above information is unclear. However, the tree-ring widths provide us one way of comparing runoff records with estimates from a much larger span of history.

Water Supply Development

The founding of the San Diego Mission in 1769 brought with it the start of water supply development in California. Water was diverted from the San Diego River to irrigate fields surrounding the mission. Similar developments accompanied other missions during ensuing years. After 1850, irrigation expanded significantly as the amount of irrigated agricultural land increased dramatically. This increase was abetted by the mining boom, which provided a nearby market for agricultural products. Since natural stream flows dropped during the summer, it was not long before small reservoirs were built to supplement low stream flows. A number of fairly large dams were built in Southern California by 1900, including Bear Valley, Hemet, Sweetwater, and

Table 3-1. Pre-1900 Dry Periods* and Droughts Since 1900

Period	*Length (years)*	*Estimated Average Runoff (maf/year)*
Based on tree ring studies		
1579-82	4	12.4
1593-95	3	9.3
1618-20	3	13.2
1651-55	5	12.3
1719-24	6	12.6
1735-37	3	12.2
1755-60	6	13.3
1776-78	3	12.1
1793-95	3	10.7
1839-41	3	12.9
1843-46	4	12.3
Based on flow measurements		
1918-20	3	12.0
1929-34	6	9.8
1959-62	4	13.0
1976-77	2	6.6
1987-92	6	10.0

*Years with runoff less than 15.7 million acre-feet per year.

Cuyamaca. Dams in Northern California were smaller and usually at the outlets of natural lakes or meadows. Total storage capacity on the Yuba River, one of the basins with a large amount of early development, exceeded 30,000 acre-feet by 1900.

During the 1920s, larger reservoirs were built in Northern California; in many cases, they were partially funded by hydroelectric power companies. Beginning in 1930, a number of critically dry years reduced snowmelt and streamflow and motivated another era of water storage development to provide more stable and reliable supplies.

There are now more than 1,200 nonfederal dams under State supervision (generally dams 25 feet or higher or those holding 50 af or more). The reservoirs formed by these dams provide a gross reservoir capacity of roughly 20 maf. There are also 181 federal reservoirs in California, with a combined capacity of nearly 22 maf. Taken together these 1,400 or so reservoirs can hold about 42 maf of water, which is a relatively small amount of storage in proportion to the 71 maf of annual runoff. The Colorado River alone, with a long-term average annual runoff of about 15 maf, has about 65 maf of storage. Table 3-5, at the end of this chapter, lists reservoirs storing 100,000 af or more in chronological order of construction.

This chapter identifies developed surface water supplies by source. (Ground water, another important source of supply, is covered in Chapter 4.) The major categories are:

- local surface and local imported supplies
- State Water Project
- Central Valley Project and other federally developed water
- the Colorado River
- water reclamation, including desalination

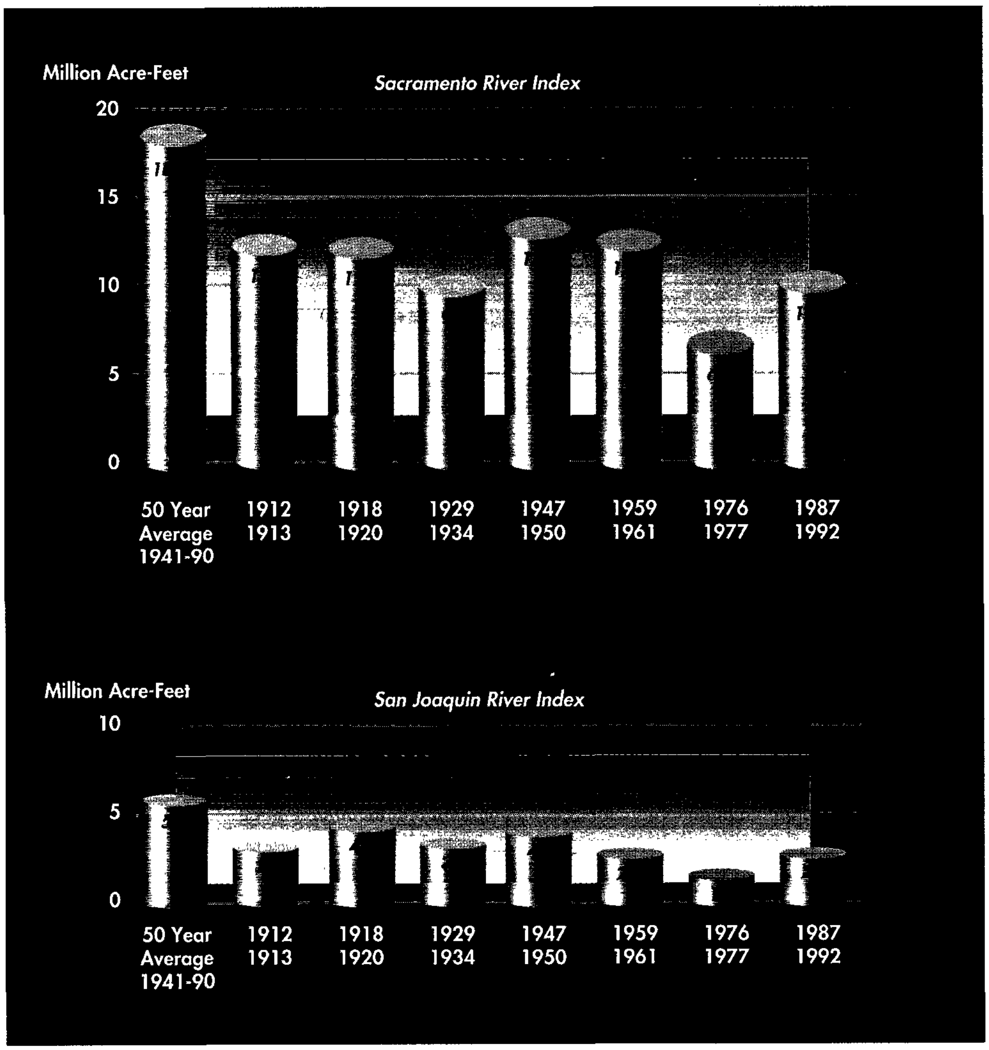

Figure 3-6. Comparison of Multi–Year Droughts Average Annual Runoff

Local and Imported Supplies

Local water projects were constructed and are operated by a wide variety of water and irrigation districts, agencies, municipalities, companies, and even individuals. Initially, local projects consisted of direct stream diversions. When these proved inadequate during the dry season, storage dams were built. As nearby sources were fully developed, urban areas began to reach out to more distant sources. Local agencies are finding it increasingly difficult to continue to undertake new water projects to meet their needs because potential sites for additional water projects are either environmentally sensitive, too costly to develop, or both. Rural areas, in particular, have limited means of repaying loans for water projects. Opportunities for local conjunctive use programs are limited because mountain and foothill ground water basins tend to be limited. On average, local surface water supply projects meet about one–third of California's water needs.

The majority of local water supplies are in–area (within one region) diversion and storage systems. Most local surface projects are relatively small, but some are large–volume projects. Some examples of these projects are the Exchequer and Don Pedro (both old and new) dams on the Merced and Tuolumne rivers. Another example is Bullards Bar Dam on the Yuba River, built by Yuba County Water Agency. Some irrigation districts have taken advantage of upstream projects built primarily for hydroelectric power production. These facilities also incidentally regulate stream flows, create more usable water supplies during the dry summer months, and provide flood control and recreational benefits.

Figure 3-9 shows regional water transfers at the 1990 level of development. Most of these transfers are through the Delta, the hub of California's surface water delivery system. Until solutions to complex Delta problems are identified and put into place, 1990 level water transfers cannot be sustained in the future.

The first long-distance, inter-regional water transfer project in California was the Los Angeles Aqueduct, completed by the City of Los Angeles in 1913. The aqueduct stretches over 290 miles from the Owens Valley and had an original capacity of 330,000 af per year. A second section was added in 1970, which increased its potential

Possible Effects of Global Climate Change

Much concern has been expressed about possible future climate change caused by burning fossil fuel and other modern human activities that increase carbon dioxide and other trace greenhouse gases in the atmosphere. World weather records indicate an overall warming trend during the last century, with a surge of warming prior to 1940 (which cannot be attributed to greenhouse gases) and a more recent rise during the 1980s. The extent to which this latest rise is real or an artifact of instrument location (heat island effect of growing cities) or a temporary anomaly is debated among climatologists. For now, most of the projections of future climate change are derived from computer climate simulation studies. Not yet well-represented in the simulation models are cloud effects, which can have a large influence on the study results.

The studies generally indicate a global average temperature rise of about 2 to 5 degrees Celsius over the next century, or about 3°C as an average, for a doubled-CO_2 atmosphere. Figures for regional changes are less dependable because of regional weather influences.

Although studies assume a doubling of atmospheric carbon dioxide content, the same effect would be produced by some combination of increased CO_2 and trace greenhouse gases, such as methane and chlorofluorocarbons, which, in total, produce the same effect as doubled CO_2. Carbon dioxide in the atmosphere has increased from an estimated 280 parts per million about 200 years ago to roughly 315 ppm in 1960 and about 355 ppm in 1993.

Although the climate models also show precipitation, there is less confidence in those results. The most important hydrologic parameter affecting water resources is regional precipitation, and model results are not considered reliable enough to use for any decisions. Some researchers have examined scenarios with ranges of precipitation, for example 10 percent drier or wetter, to obtain insights into how sensitive water systems are to these changes.

Sea level rise is inferred largely from projected temperature increases and is less certain. Causes would be thermal expansion as the ocean warms and melting of permanent ice fields and glaciers. Average projections of sea level rise call for about 1 foot by the middle of the next century, which would represent a strong increase over the roughly 0.5-foot rise estimated for the past 100 years.

Reduced Mountain Snowpack and Shift in Runoff Patterns

For California, if global warming occurs, the most likely impact would be a shift in runoff patterns, with less and earlier runoff from snowmelt and more winter runoff from the higher mountain areas. This change in runoff directly relates to the temperature; the warmer temperatures would mean higher snow levels during winter storms, more cool-season runoff, and less carryover into late spring and summer (assuming precipitation remains the same).

annual deliveries to 480,000 af per year. However, these projects were developed without minimum flows for fisheries in creeks tributary to Mono Lake and without consideration of lake levels. Environmental problems resulting from diversions have resulted in recent restrictions on the use of water tributary to Mono Lake and on ground water pumping in the Owens Valley (see Chapter 2). These restrictions have reduced the dependable supply of the Los Angeles Aqueduct to about 200,000 af in drought years.

In the 1920s, the East Bay cities of the San Francisco Bay Region turned to Sierra Nevada watersheds for additional water. The East Bay Municipal Utility District completed the Mokelumne Aqueduct from Pardee Reservoir in 1929. With the addition of a third barrel in 1965, this aqueduct's capacity was increased from 224,000 af per year to 364,000 af per year. Camanche Reservoir was added in 1963. Again, drought

If average temperatures warm by 3°C and this change applies to winter season storm systems, it would lift average snowline levels by about 1,500 feet. Compared to today, the portion of California's winter precipitation stored in the mountain snowpack would decrease significantly. The impact in the northern Sierra Nevada would be larger than in the higher elevation southern Sierra Nevada. Preliminary estimates (assuming the same average precipitation amounts and patterns) indicate that this shift would reduce the average April to July snowmelt runoff by about one–third. A corresponding increase in runoff would be expected during the winter, when it often would have to be passed through major reservoirs as flood control releases. There would be some loss in water supply yield if the shift in snowmelt runoff occurs.

Impact of Sea Level Rising

If sea level rises, it could have a major impact on California water transfers through the Sacramento–San Joaquin Delta. There are two primary problems: (1) a slight increase in ocean salinity intrusion due to deeper channels and, partly because of less uncontrolled spring runoff, a longer season of relatively low Delta outflows, and (2) problems with levees protecting the low-lying land. Both problems would degrade the quality and reliability of fresh water transfer supplies pumped at the southern edge of the Delta with existing facilities and operations.

Potential Increase in Sizes of Large Floods

There is a general relationship between rainfall intensity and the warmness of the climate. Other factors being equal, warm air holds more water vapor than cool air. Lifting of the air, either orographically by a mountain range, by convective activity (thunderstorms), or by a weather system front, then has the potential for greater precipitation intensity. Also, higher snow levels in the Sierra Nevada mean more direct rain runoff and less snow accumulation. Major floods on California's rivers are produced by slow–moving Pacific storm systems which sweep moist subtropical air from the southwest into California. When these moisture–laden air streams run into the mountains, copious amounts of rain and runoff result as the southwesterly winds are lifted to cross the Sierra Nevada and coastal mountain ranges (orographic effect). Whether the southwesterly winter storm winds would be stronger or weaker if global warming occurs has not been determined.

These three potential impacts and other possible changes will probably be slow to develop because climate change is expected to be gradual. The uncertainty about potential changes is high, and there should be time for confirmation of these changes and time to adapt. It is useful to monitor climate changes, however, and determine how they may affect current water supply systems.

year supplies in the Pardee–Camanche Reservoir system are not always adequate to sustain full aqueduct capacity diversions.

In 1934, the City of San Francisco completed the Hetch Hetchy Aqueduct system, which diverts water from the Tuolumne River to serve San Francisco, San Mateo, northern Santa Clara, and portions of southern Alameda counties. (Hetch Hetchy Dam began operating in 1923.) The current conveyance capacity of the Hetch Hetchy Aqueduct is about 330,000 af per year. Its primary supply reservoirs are Hetch Hetchy, Lake Lloyd (Cherry Valley), and Lake Eleanor. The City of San Francisco also has exchange water storage in Don Pedro Reservoir which allows water that would otherwise go to Turlock and Modesto irrigation districts to be diverted through the Hetch Hetchy Aqueduct.

Figure 3-7. Storage in 155 Major Reservoirs in California October 1

Note: The 1987-92 storage amounts include New Melones and Warm Springs reservoirs which began operation after 1977. The 1989-92 storage amounts include the new Spicer Meadows Reservoir on the Stanislaus River.

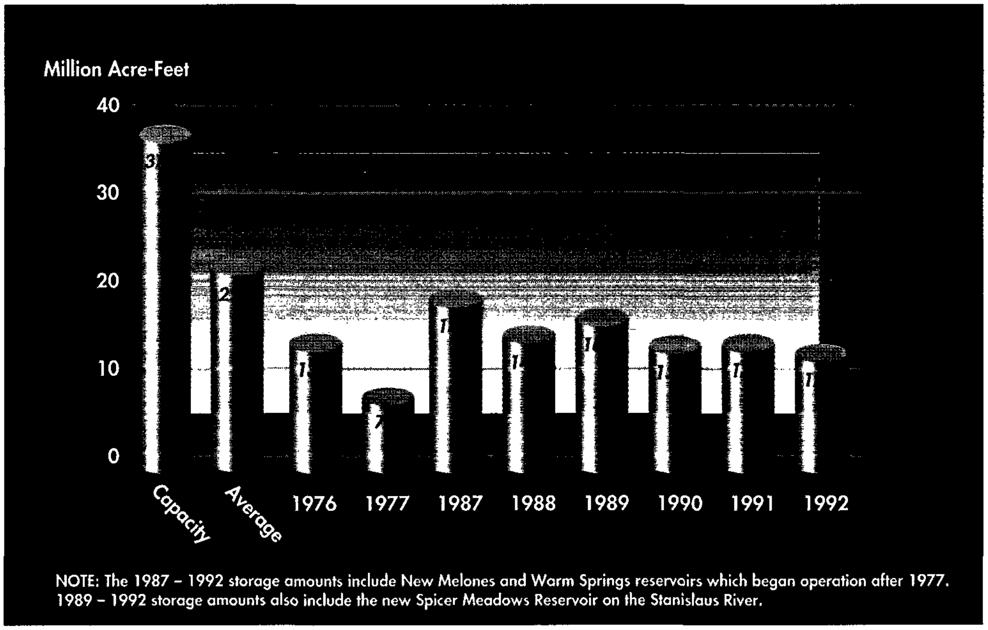

Figure 3-8. Historical Development of Reservoir Capacity (reservoirs of 50,000 acre-feet or more)

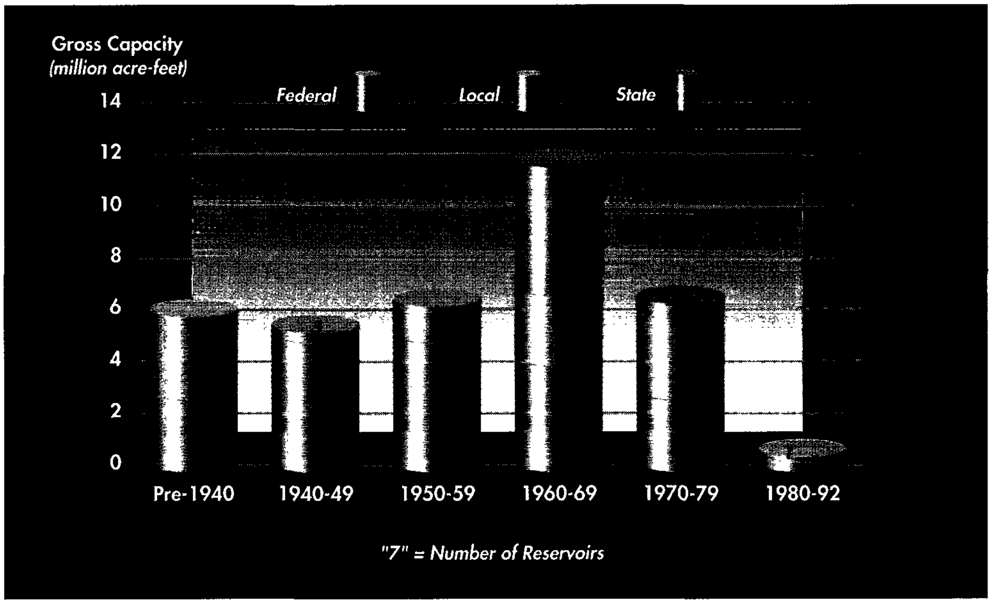

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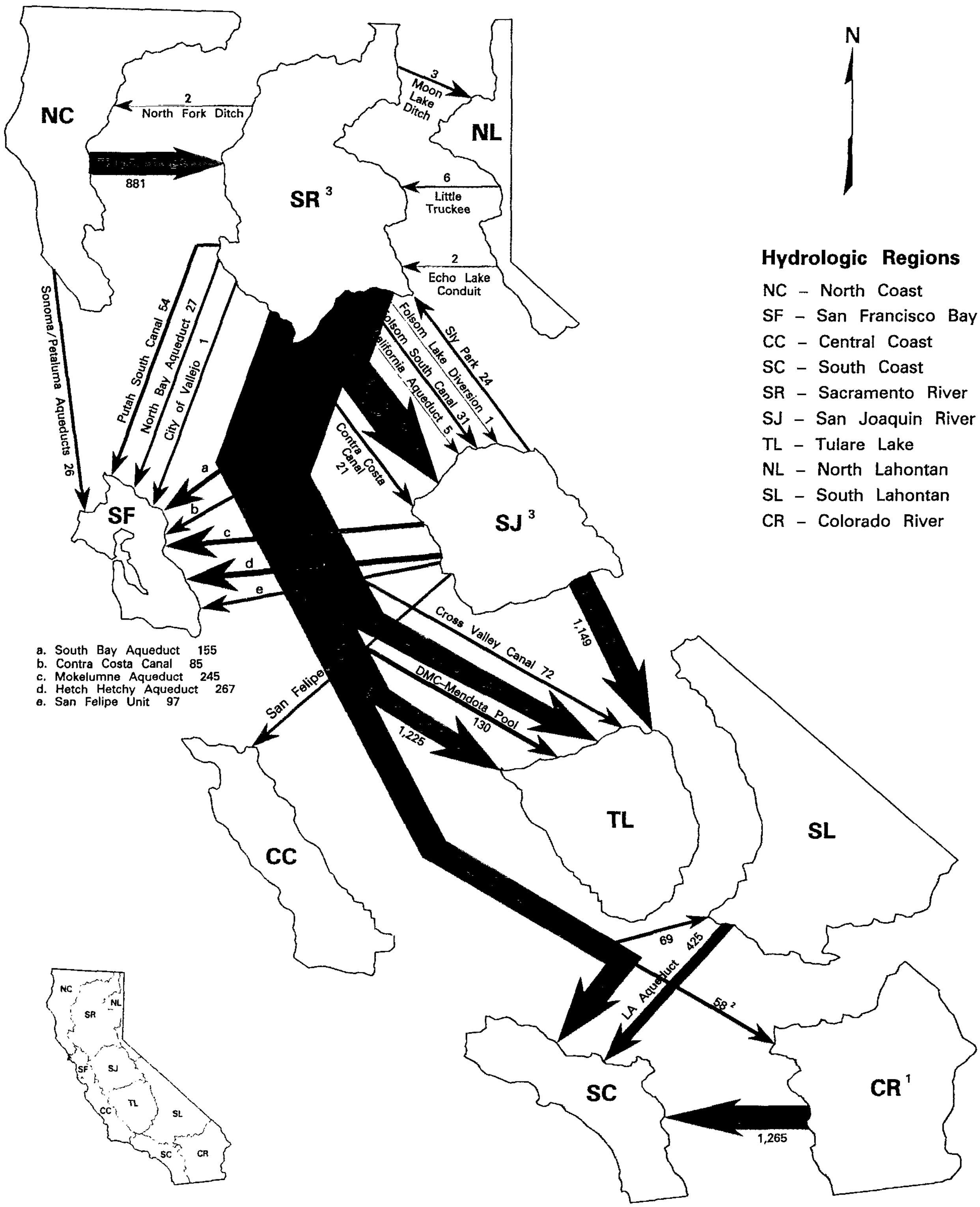
Figure 3-9. Regional Water Transfers at 1990 Level of Development

(thousands of acre–feet per year)



[1] *Total California Colorado River Usage* [2] *Exchange*
[3] *Transfers from the Sacramento-San Joaquin Delta are taken from commingled waters originating in both the Sacramento River and San Joaquin River Regions.*

The All-American Canal System was authorized under the Boulder Canyon Project Act of December 21, 1928. It diverts Colorado River water to the Imperial and Coachella valleys. Construction began in 1934, following construction of Hoover Dam on the Colorado River. The first deliveries of irrigation water to Imperial Valley were in 1940. The Coachella Canal and distribution system was completed in 1954. The Imperial Irrigation District assumed responsibility for operation and maintenance of the All-American Canal in 1952. The Coachella Valley Water District is responsible for the operation and maintenance of the Coachella Canal portion of the system. The system has the capacity to divert over 3 maf annually from the Colorado River for use in the Imperial and Coachella valleys.

The fifth major inter-regional conveyance project in California built by a local agency is the Colorado River Aqueduct, which diverts Colorado River water from Lake Havasu above Parker Dam to the South Coast Region. Constructed in the 1930s by the Metropolitan Water District of Southern California, this aqueduct began operation in 1941. The Colorado River Aqueduct was sized for about 1.2 maf per year but has carried as much as 1.3 maf during some of the recent drought years. (See the *Colorado River* section in this chapter.)

The preceding local import systems are not the only ones in California, but they account for over 95 percent of the local project water transferred among hydrologic regions.

State Water Project

Planning for the multipurpose State Water Project began soon after World War II when it became evident that local and federal water development could not keep pace with the state's rapidly growing population. Voters authorized construction of the project in 1960 by ratifying the Burns-Porter Act. At that time, the plans recognized that there would be a gradual increase in water demand and that some of the supply facilities could be deferred until later. The SWP's major components include the multipurpose Oroville Dam and Reservoir on the Feather River, the Edmund G. Brown California Aqueduct, South Bay Aqueduct, North Bay Aqueduct, and a portion of San Luis Reservoir. Delta water transfer facilities were part of the original plan, and additional Sacramento and North Coast basin supply reservoirs were envisioned. Contracts were signed for an eventual delivery of 4.23 maf. Service areas of the present 29 contracting agencies are shown in Figure 3-10. Figure 3-12 depicts a history of SWP water deliveries from 1962 to 1993. Generally, San Joaquin Valley use of SWP supply has been near full contract amounts since about 1980 (except during very wet years and during deficient-supply years), whereas Southern California use has only built up to about 60 percent of full entitlement.

The initial features of the SWP begin with three small reservoirs in the upper Feather River basin in Plumas County: Lake Davis, and Frenchman and Antelope Lakes. Farther downstream in the foothills of the Sierra Nevada is the 3.5-maf Lake Oroville, the second largest reservoir in California, where winter and spring flows of the Feather River are stored (see Figure 3-11). The 444-mile California Aqueduct is the state's largest and longest water conveyance system, beginning in the southwest Delta at Banks Pumping Plant and extending to Lake Perris south of Riverside, in Southern California. Delta water is pumped southward and westward, with amounts exceeding immediate needs temporarily stored in the 2.0-maf San Luis Reservoir (which is shared with the CVP). Of the contracted amounts, about 2.5 maf of water is destined for south of the Tehachapis, nearly 1.36 maf to the San Joaquin Valley, and the remaining 0.37 maf to the San Francisco Bay and Central Coast regions and the Feather River area. At

Figure 3-10. State Water Project Service Areas

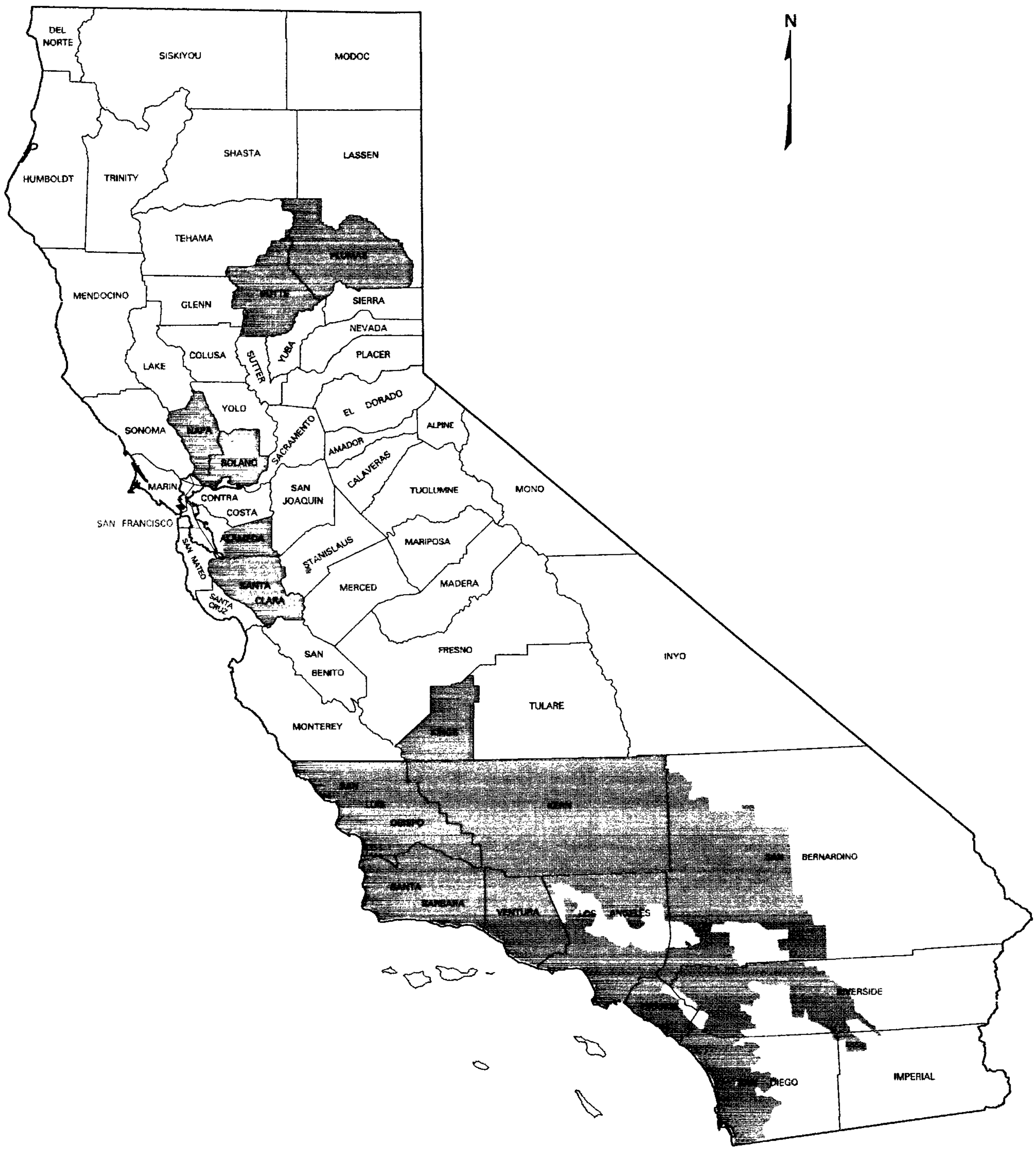


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Figure 3-11. Major State Water Project Facilities

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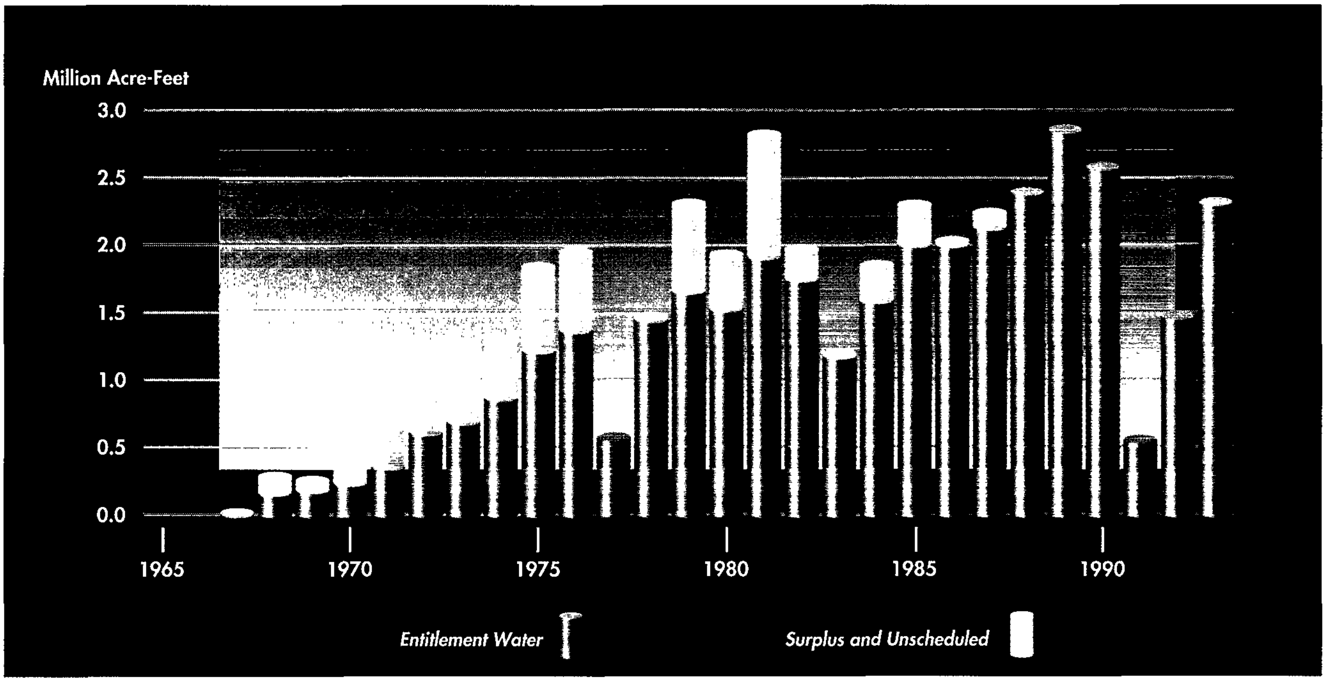


Figure 3-12. State Water Project Deliveries 1967–1993

the southern end of the San Joaquin Valley, pumps at the Edmonston Pumping Plant lift water 1,926 feet, sending flows through the Tehachapi Mountains by tunnels and into Southern California. Slightly over 1.5 maf was pumped at Edmonston Pumping Plant in 1990.

The estimated seven-year average dry-period yield of the SWP with its current facilities operating according to Water Right Decision 1485 requirements is about 2.4 maf per year. Entitlement demand of SWP contractors for the year 2010 is an estimated 4.1 maf. To augment project supply, additions to the SWP are proposed and include: Delta facilities; interim south Delta facilities; the Kern Water Bank; Los Banos Grandes; and possible conjunctive use of surface storage and ground water in the Sacramento and San Joaquin valleys; and short- and long-term water purchases. These projects and programs are discussed in Chapter 11.

In the short-term, SWP contractors relying on the Delta for all or a portion of their supplies face great uncertainty in terms of water supply reliability due to the uncertain outcome of a number of actions currently being undertaken to protect aquatic species in the Delta. Until solutions to complex Delta problems are identified and put into place, many will experience more frequent and severe water supply shortages.

Central Valley Project

The U.S. Bureau of Reclamation's Central Valley Project is the largest water storage and delivery system in California, covering 29 of the State's 58 counties. The project's features include 18 federal reservoirs, plus 4 additional reservoirs jointly owned with the State Water Project (primarily the San Luis Reservoir). The keystone of the CVP is the 4.6-maf Lake Shasta, the largest reservoir in California. The reservoirs in this system provide a total storage capacity of slightly over 12 maf, nearly 30 percent of the total surface storage in California, and deliver about 7.3 maf annually to agricultural, urban, and wildlife uses.

The federal government began construction of the CVP in the 1930s, as authorized under the Rivers and Harbors Act of 1937. CVP purposes expanded to include

Table 3-2. Major Central Valley Project Reservoirs

Reservoir Name	Capacity (thousands of acre-feet)
Shasta	4, 552
Clair Engle	2,448
Whiskeytown	241
Folsom	977
New Melones	2,420
Millerton	520
San Luis (federal share)	971

river regulation, flood control, and navigation; later reauthorization included recreation and fish and wildlife purposes. Initial authorization covered facilities such as Shasta and Friant Dams, Tracy Pumping Plant, and the Contra Costa, Delta-Mendota, and Friant-Kern Canals. Later authorizations continued to add additional facilities such as Folsom Dam (authorized in 1949), San Luis Unit (authorized in 1960), and New Melones Dam (authorized in 1962).

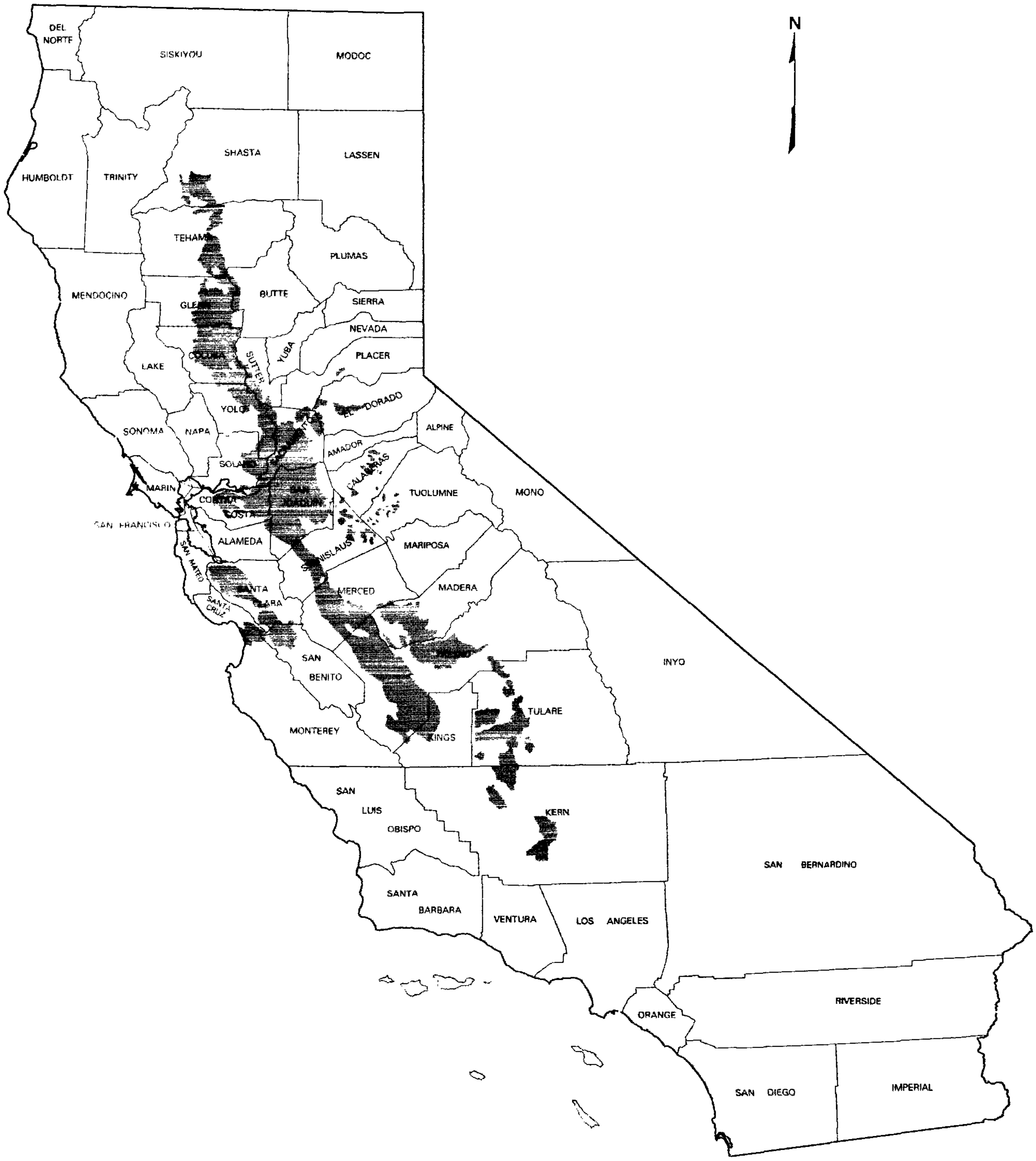
A large 2.3-maf multipurpose dam, primarily for flood control and water supply on the American River, Auburn Dam, was authorized by Congress in 1965 as an addition to the Central Valley Project. Foundation and other preparatory work for construction were halted by concerns for safety caused by the 1975 Oroville earthquake. After study, the dam's design was changed in 1980 from a concrete arch to a gravity structure. Cost estimates have exceeded the original authorization, so new authorization is needed before work can resume. The proposed dam is now a source of controversy between proponents and those who wish to preserve the American River canyon as is. As currently planned, Auburn Reservoir could have provided somewhat over 0.3 maf per year of new water yield to the CVP.

The flood of 1986 revealed that flood protection in the metropolitan Sacramento area is inadequate. In 1992, a proposal by the Corps of Engineers to build a 500,000-acre-foot "dry dam" for flood control only at the Auburn site did not pass Congress because of opposition from environmentalists and from supporters of a multipurpose dam. The Corps of Engineers and USBR, in cooperation with local agencies and the State, are continuing studies to develop a management plan for the American River to provide for the area's flood control and water supply needs.

The CVP supplies water to over 250 long-term water contractors in the service areas shown in Figure 3-13, whose contracts total 9.3 maf including 1.4 maf of Friant Division Class 2 supply available in wet years. Of the 9.3 maf, 6.2 maf is project water and 3.1 maf is water right settlement water. Average-year deliveries in the past decade have been around 7 maf. Water right settlement water is water covered in agreements with water rights holders whose diversions were in existence before the project was constructed. Since construction of project reservoirs altered the rivers' natural flow upon which these diverters had relied, contracts were negotiated to serve the users stored water to supplement river flows available under their rights. CVP water right settlement contractors (called *prior right holders*) on the upper Sacramento River receive their supply from natural flow and storage regulated at Shasta Dam; settlement contractors on the San Joaquin River (called *exchange contractors*) receive Delta water via the Delta-Mendota Canal as explained below.

About 90 percent of the CVP water has gone to agricultural uses in the recent past; this includes water delivered to prior right holders. CVP water is used to irrigate

Figure 3-13. Central Valley Project Service Areas

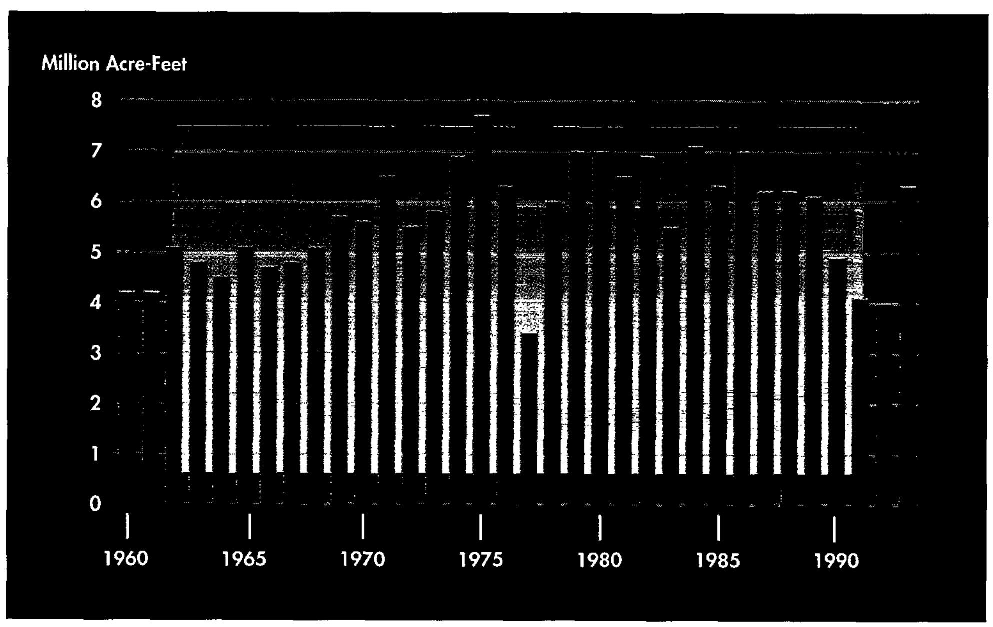


some 19,000 farms covering 3 million acres. Currently, increasing quantities of water are being served to municipal customers. Urban areas receiving CVP water supply include Redding, Sacramento, Folsom, Tracy, most of Santa Clara County, northeastern Contra Costa County, and Fresno. Recent firming up of environmental supplies under the provisions of the CVP Improvement Act of 1992 are described in Chapter 2.

Water stored in CVP northern reservoirs is gradually released down the Sacramento River into the Sacramento-San Joaquin Delta, where it helps meet demand along the river and quality and flow requirements in the Delta. The remainder is exported via the Contra Costa Canal and the Delta-Mendota Canal. Excess water during the winter is conveyed to off-stream San Luis Reservoir on the west side of the valley for subsequent delivery to the San Luis and San Felipe units. A portion of the Delta-Mendota exports are placed back into the San Joaquin River at Mendota Pool to serve, by exchange, water users who have long-standing historical rights to use of San Joaquin River flow. This exchange enabled the CVP to build Friant Dam, northeast of Fresno, and divert a major portion of the flow there farther south in the Friant-Kern Canal (and some water northward in the Madera Canal). The Corning and Tehama-Colusa Canals serve an area on the west side of the Sacramento Valley. Other water supplies are furnished to districts and water rights holders in the Sacramento Valley. American River water stored in Folsom Reservoir is used mainly for stream flow and Delta requirements, including CVP exports. More recently, the San Felipe Unit was added to serve coastal counties west of San Luis Reservoir. New Melones Reservoir will be serving an area on the eastern side of the San Joaquin Valley as well as providing downstream water quality and fishery flows. Operations in the Delta are coordinated with the SWP to meet water quality and other standards set by the State Water Resources Control Board, and more recently by federal fisheries agencies.

Figure 3-14 shows historical CVP water deliveries since 1960. The drop in 1977 and 1990-92 deliveries was caused by shortages in supply during the critically dry years. CVP water deliveries to agricultural and urban users have been reduced by the passage of the CVP Improvement Act of 1992. As a result, CVP contractors will undergo more frequent and severe shortages. (A more comprehensive discussion about the CVP Improvement Act is in Chapter 2.) Figure 3-15 shows a history of CVP hydroelec-

Figure 3-14. Central Valley Project Deliveries 1960-1993



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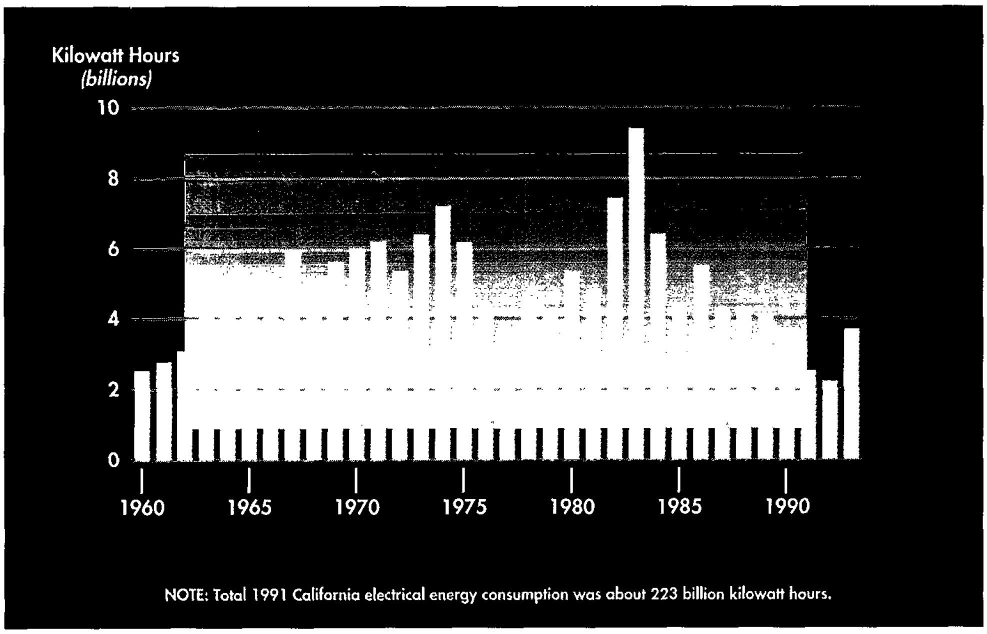


Figure 3-15. Central Valley Project Annual Hydroelectric Energy Production 1960–1993

tric energy production since 1960. Note the substantial drop in hydroelectric production during the 1987–92 drought.

In the short-term, CVP contractors relying on the Delta for all or a portion of their supplies face great uncertainty in terms of water supply reliability due to the uncertain outcome of a number of actions currently being undertaken to protect aquatic species in the Delta. Until solutions to complex Delta problems are identified and put into place, many will experience more frequent and severe water supply shortages. For example, in 1993, an above-normal runoff year, environmental restrictions limited CVP deliveries to Westlands Irrigation District to only 50 percent of contracted supply. Further, the CVPIA reallocates 800,000 af of CVP supplies for fisheries in Central Valley streams; 200,000 af for wildlife refuges in the Central Valley; and about 120,000 af of increased flow for the Trinity River.

Other Federal Projects

Other federal water projects include those constructed by the U.S. Army Corps of Engineers or the U.S. Bureau of Reclamation. Some of the larger projects in this category are: the Klamath Project on the California–Oregon border; the Orland Project on Stony Creek (west side of the Sacramento Valley); the Solano Project on Putah Creek,which stores water in Lake Berryessa in Napa County and conveys water through Putah South Canal in Solano County; New Hogan Reservoir in Calaveras County; the four major dams and reservoirs on the east side of the Tulare Lake Region—Pine Flat, Terminus, Success, and Isabella; and Cachuma and Casitas reservoirs in Santa Barbara and Ventura counties. Altogether these projects deliver about 1.2 maf annually.

Colorado River

In a 1964 U.S. Supreme Court decree, annual use of 7.5 maf of Colorado River water was apportioned among the three lower division states of Arizona, Nevada, and California. Arizona could begin using its apportionment of 2.8 maf now that the Central Arizona Project is operating, but current repayment issues associated with sales of water to agricultural users are delaying the buildup in demand. Arizona's Colorado River water use in 1993 was 2.2 maf. Nevada's water use is expected to reach

Figure 3-16. Colorado River Service Areas

its 0.3-maf apportionment in a little over a decade. Nevada used 0.18 maf in 1993. California's use in 1993 was about 4.8 maf.

California's basic apportionment of Colorado River supplies is 4.4 maf per year, plus half of any excess or surplus water. Because of wet winters in the early to mid-1980s, and because Arizona and Nevada were not yet using their full apportionment, California has been able to use from 4.5 to 5.2 maf annually between 1986 and 1992. Since 1980, the highest and the lowest sequence of unregulated Colorado River runoff has occurred, with the peak year in 1984 and the driest in 1990. Between 1988 and 1992, Colorado River runoff was far below average, and by 1991 storage on the main river system fell to less than average. Runoff in 1993 was above average and, by July 1, storage in Lakes Mead and Powell had increased about 6 maf over the previous year's storage. California's use of Colorado River water can be limited in the future to 4.4 maf in any year by the Secretary of the Interior.

The agricultural water diverters in the Colorado River Region are Palo Verde Irrigation District, Imperial Irrigation District, the Reservation Division of the Yuma Project, and Coachella Valley Water District (see Figure 3-16). These water users have priority rights to the first 3.85 maf of California's Colorado River supply. This would leave 550,000 af, less the water used by Native Americans, for MWDSC's Colorado River Aqueduct, instead of the 1.2 maf that it has been using in recent years. Further reductions in Metropolitan's supply are also expected; 55,000 af may be used by Native American Tribes and others along the Colorado River. To partially offset potential reductions, MWDSC has executed a number of agreements to increase its water supplies. In December 1988, Imperial Irrigation District and MWDSC reached an agreement that provides funding for conservation projects in the Imperial Valley after the State Water Resources Control Board issued order WR 88-20 requiring IID to conserve 100,000 af per year within a certain period of time. When completed, these projects will save an estimated 106,000 af of water annually. MWDSC is funding the construction, operation, and maintenance of the projects; the estimated total cost is $222 million (1988 dollars). In exchange, MWDSC will be able to divert additional water, under certain conditions, from the Colorado River through its Colorado River Aqueduct. The amount of additional Colorado River water MWDSC diverts is to be equivalent to the amount of water conserved through the MWDSC-financed projects in the event MWDSC's available allocation is reduced to an amount below its aqueduct capacity. As the result of a contract between the Coachella Valley Water District and the United States, the first 49 miles of the Coachella Canal were lined to save 132,000 af annually, which can also be made available to MWDSC under certain conditions.

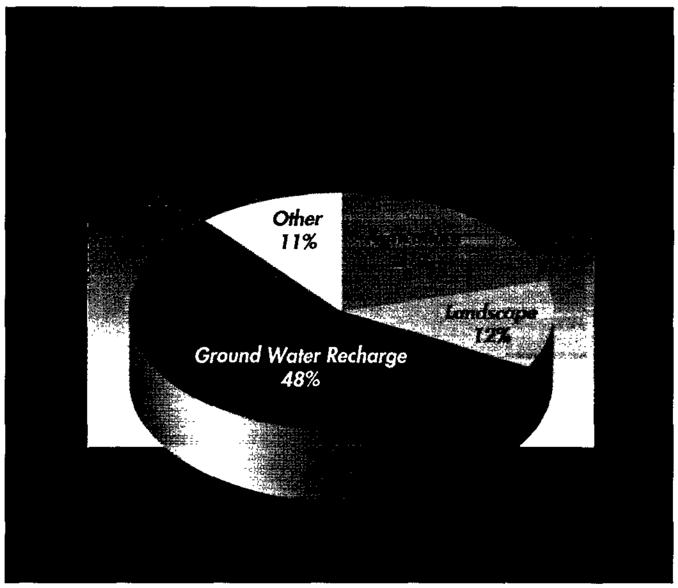
Water conservation measures implemented by IID since 1954 have decreased the amount of water entering the Salton Sea. With less relatively fresh water entering the Salton Sea, its salinity concentrations have increased somewhat more rapidly than would have happened otherwise and have affected the artificial fishery planted by DFG. The State Water Resources Control Board considered this matter in issuing order WR 88-20. Implementation of the water conservation measures has also reduced the potential for flooding from higher Salton Sea stages.

Water Recycling

Water recycling, formerly known as waste water reclamation, has been intentionally used as a source of nonpotable water in California for nearly a century. In recent years, more stringent treatment requirements for disposal of municipal and industrial waste water have reduced the incremental cost of obtaining the higher level of treatment required for use of recycled water. This higher level is needed so that recycled water can be safely used for a wider variety of applications. Part of the recycled water used will lessen demand for new fresh water supplies.

Technology available today allows municipal waste water treatment systems in some regions to consistently produce safe water supplies at competitive costs. The degree of treatment depends on the intended use, and public health protection is the paramount criterion for judging the level of treatment needed. As a minimum, waste water is treated to a secondary level to remove dissolved organic materials. Secondary effluent can be treated to a tertiary level by additional filtering and disinfecting, but the cost can be high in comparison to other fresh water supply augmentation options. Sometimes reverse osmosis desalination may be required to reduce the salt content; in such cases, it is possible for the recycled water to be of higher quality than the original source. However, the added costs of desalination can make water recycling infeasible in many regions.

Figure 3-17. Present Use of Recycled Water



A July 1993 report by the WateReuse Association of California summarized present and future potential water recycling data gathered during a 1992 survey. About 240 agencies were contacted, and 111 responded to the survey. Its purpose was to determine the agencies' plans, projections, and vision for future water reuse. One of the purposes of the survey report was to encourage agencies to set realistic goals, and develop long–term strategies to better meet future water needs. It was noted that water reuse had increased from about 270,000 af per year in 1987 to over 380,000 af per year by 1993. Water reuse as reported in the 1993 survey is shown in Figure 3-17 and Table 3-3. Future estimates for water recycling are discussed in Chapter 11.

Table 3-3. Present Use of Recycled Water by Category

Type of Reuse	*Rate of Reuse (thousands of acre-feet per year)*	*Percent of Total*
Agricultural Irrigation	80	21
Ground Water Recharge	185	48
Landscape Irrigation	47	12
Environmental Uses (Wildlife Habitat)	29	8
Industrial, Seawater Intrusion Barriers, and Miscellaneous Uses (Recreational and Others)	43	11
TOTAL	384	100

Adapted from *WateReuse 1993 survey, Future Water Recycling Potential, July 1993.* (1992 level of recycling)

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Most of the 384,000 af recycled is in the South Coast, Central Coast, and Tulare Lake regions. Some uses of recycled water, such as environmental enhancement or landscape projects, are new uses that would not have received fresh water in the absence of a water recycling project because imported fresh water was too costly or not available. In addition, outflow from waste water treatment plants in the Central Valley is generally put into streams or ground water basins and reused. Recycling of such outflow, therefore, does not generate new water supply.

Some constraints to fully implementing all potential water recycling options include:

- Distances to potential applications, particularly as nearby agricultural land is displaced by urban development.
- Relatively high mineral content of waste water, especially where the quality of water supply is poorer or sewage is contaminated by saline ground water.
- Acceptance by the public and health authorities.
- Regional economics, energy, and funding for new water recycling plants.
- Regulatory requirements, including Regional Water Quality Control Board, health agency, and other governmental approvals necessary to implement new projects. On the other hand, some regulations (for example, Chapter 553 of the California Code of Regulations) can encourage reuse by prohibiting use of fresh water for certain purposes, such as golf courses or parks, when suitable reclaimed water is available.
- Salt disposal problems.

Table 3-4 specifies a number of possible nonpotable uses of recycled water and the degree of treatment necessary for the type of use, as assessed by the California Department of Health Services in 1992. The "Disinfected Secondary-2.2" column indicates the higher standard of 2.2 coliform bacteria per 100 milliliters, and the "Disinfected Secondary-23" column indicates the less-treated reclaimed water containing 23 coliform bacteria per 100 milliliters.

The potential for increased use of recycled water in the future depends on many factors and is discussed in Chapter 11. The primary source of raw supply would be the estimated 2.5 to 3 maf of treated wastewater discharged annually into the ocean from California's coastal cities. Smaller amounts of reclaimed water could come from reclaiming brackish ground water, including contaminated ground water or ground water with high nitrate content, and from desalination of ocean water.

Other Water Supplies

Several unconventional methods have been used to augment surface water supply in certain areas of California: use of gray water, long-range weather forecasting, watershed management, weather modification, and sea water desalination.

Gray Water

For the residential homeowner, some waste water can be directly reused as gray water (used household water). Gray water can be used in subsurface systems to irrigate lawns, fruit trees, ornamental trees and shrubs, flowers, and other ornamental ground cover. Water from the bathroom sink, washing machine, bathtub, or shower is generally safe to reuse, whereas water from a toilet, kitchen sink, or dishwasher or water used in washing diapers should not be directly reused. Care must be taken so that children and others do not come in direct contact with gray water, and any food from areas irrigated by subsurface systems that use gray water should be rinsed and cooked before being consumed.

Table 3-4. Suitable Uses of Recycled Water

Use	*Conditions in Which Use Is Allowed* *Disinfected Tertiary*	*Disinfected Secondary*	*Disinfected Secondary*	*Undisinfected Secondary*
Irrigation of:				
Parks, playgrounds, school yards, residential yards, and golf courses associated with residences	Spray, drip, or surface	Not allowed	Not allowed	Not allowed
Restricted access golf courses, cemeteries, and freeway landscapes	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Not allowed
Non-edible vegetation at other areas with limited public exposure	Spray, drip, or surface	Spray, drip, or surface[a]	Spray, drip, or surface[a]	Not allowed
Sod farms	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Not allowed
Ornamental plants for commercial use	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Not allowed
All food crops	Spray, drip, or surface	Not allowed	Not allowed	Not allowed
Food crops that are above ground and not contacted by reclaimed water	Spray, drip, or surface	Drip or surface	Not allowed	Not allowed
Pasture for milking animals and other animals	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Not allowed
Fodder (e.g., alfalfa), fiber (e.g., cotton), and seed crops not eaten by humans	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Drip or surface
Orchards and vineyards bearing food crops	Spray, drip, or surface	Drip or surface	Drip or surface	Drip or surface
Orchards and vineyards not bearing food crops during irrigation	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Drip or surface
Christmas trees and other trees not grown for food	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Drip or surface
Food crop which must undergo commercial pathogen-destroying processing before consumption (e.g., sugar beets)	Spray, drip, or surface	Spray, drip, or surface	Spray, drip, or surface	Drip or surface
Other Uses:				
Supply for a nonrestricted impoundment	Allowed	Not allowed	Not allowed	Not allowed
Supply for a restricted recreational impoundment	Allowed	Allowed	Not allowed	Not allowed
Industrial cooling using cooling towers, forced air evaporation, spraying, or other feature that creates aerosols or other mist	Allowed	Not allowed	Not allowed	Not allowed
Industrial cooling not using cooling towers, forced air evaporation, spraying, or other feature that creates aerosols or other mist	Allowed	Allowed	Allowed	Not allowed
Industrial process with exposure of workers	Allowed	Not allowed	Not allowed	Not allowed
Industrial process without exposure of workers	Allowed	Allowed	Allowed	Not allowed
Industrial boiler feed	Allowed	Allowed	Allowed	Not allowed

(a) Use is not allowed if part of a park, playground, or school yard.

Gray water has been used by some homeowners in certain coastal urban areas during extreme drought to save their landscaping. In the past, health concerns and lack of information limited use of gray water. In 1992, recognizing that gray water could be used safely with proper precautions, the California Legislature amended the Water Code to allow gray water systems in residential buildings subject to appropriate

Table 3-4. Suitable Uses of Recycled Water (Continued)

Use	Conditions in Which Use Is Allowed: Disinfected Tertiary	Disinfected Secondary	Disinfected Secondary	Undisinfected Secondary
Dampening soil for compaction at construction sites, landfills, and elsewhere	Allowed	Allowed	Allowed	Not allowed
Washing aggregate and making concrete	Allowed	Allowed	Allowed	Not allowed
Dampening unpaved roads and other surfaces for dust control	Allowed	Allowed	Allowed	Not allowed
Flushing sanitary sewers	Allowed	Allowed	Allowed	Not allowed
Washing yards, lots, and sidewalks	Allowed	Allowed	Not allowed	Not allowed
Supply for landscape impoundment without decorative fountain	Allowed	Allowed	Allowed	Not allowed
Supply for decorative fountain	Allowed	Not allowed	Not allowed	Not allowed

Source: California Department of Health Services, August 17, 1992.
Copies of the full text of *Draft Language for Amendments to Title 22* are available from Department of Health Services.

standards and with the approval of local jurisdictions. Statewide, residential use of gray water will be legal by fall 1994.

Long-Range Weather Forecasting

Accurate advance weather information—extending weeks, months, and even seasons ahead—would be invaluable in planning water operations in all types of years—wet, dry, and normal. Had it been known, for instance, that 1976 and 1977 were to be extremely dry years or that the drought would end in 1977, water operations would have been planned somewhat differently and the impacts of the drought could have been lessened. The response to the 1987-92 drought might have been slightly improved by storing more water in the winter of 1986-87, pursuant to a forecast, and using more of the remaining reserves in 1992, the last year of the drought.

The potential benefits of dependable long-range weather forecasts could probably be calculated in hundreds of millions of dollars, possibly even in billions, and the value would be national. For this and other reasons, research programs to investigate and develop such forecasting capability would most appropriately be conducted at the national level. The National Weather Service routinely issues 30- and 90-day forecasts, and the Scripps Institution of Oceanography in San Diego, California (until recently), and Creighton University in Omaha, Nebraska, are engaged in making experimental forecasts. However, their predictions are not sufficiently reliable for project operation. These may be improved by current research on global weather patterns including the El Nino-Southern Oscillation in the eastern Pacific Ocean.

Weather Modification

Weather modification, commonly known as cloud seeding, has been widely practiced in California for many years. Most projects have been along the western slopes of the Sierra Nevada and some of the coast ranges. Before the recent drought, there were about 10 to 12 weather modification projects operating, with activity typically increasing during dry years. By spring 1991, the number of programs operating in California had increased to 20. New projects started during the drought include programs involving the Lake Berryessa area; San Gabriel Mountains; Calaveras, Tuolumne, Monterey, San Luis Obispo, San Diego, and eastern Santa Clara counties; and the SWP experimental propane project in the upper Feather River basin. A couple of programs were dropped in the 1992–93 season, when 18 programs were ready to operate. (Many areas suspended operations later as the winter turned wet.)

Operators engaged in cloud seeding have found it beneficial to seed rain bands along the coast and in orographic clouds over the mountains. The projects are operated to increase water supply or hydroelectric power. Although precise evaluations of the amount of water produced are difficult and expensive to determine, estimates range from a 2- to 15-percent increase in annual precipitation, depending on the number and type of storms seeded.

The Department of Water Resources, on behalf of the SWP, began a planned five-year demonstration program of cloud-seeding in the upper middle fork Feather River basin during the 1991–92 season. The project was testing the use of pure liquid propane injected into the clouds from generators on a mountain-top. The liquid propane is essentially a chilling agent that helps produce ice crystal nuclei and enhance snowfall. The program was terminated after three years, in 1994, due to several overriding considerations.

A 1993 U.S. Bureau of Reclamation feasibility study for a cloud seeding program in the watersheds above Shasta and Trinity Dams indicated good potential for the Trinity River Basin, but the study cast doubt about the effectiveness of a project for Shasta Lake. The Bureau has done substantial cloud seeding research in the Colorado River Basin. In September 1993, it published *Validation of Precipitation Management by Seeding Winter Orographic Clouds in the Colorado River Basin*. However, the Bureau is phasing out its participation in weather modification projects.

Interest in using cloud seeding to provide both short-term and long-term drought relief remains high. The technique is more successful in near-normal years, when more moisture in the form of storm clouds is present to be treated. It is also more effective when combined with carryover storage to take full advantage of additional precipitation and runoff.

Watershed Management

Watershed management can increase stream flow by controlling the growth of vegetation, usually by reducing the density of brush and tree cover and increasing the portion in grasses. In other cases, vegetation management that encourages growth of certain species can protect watersheds by reducing soil erosion, thereby reducing sedimentation in reservoirs and canals. Water supply gained by such means, although a small fraction of total runoff, can cost less than supplies developed by more conventional means. However, extensive expanses of land must be managed to significantly increase statewide supplies. The primary purposes of vegetation management today are to improve range, reduce wildfires, and enhance wildlife habitat.

National forest lands provide about half of the stream flow runoff in the state. National forest management plans show that if the present management plans had been in place prior to 1982, the average runoff from national forests would have been increased by about 290,000 acre-feet (an increase of nearly 1 percent). Much of this water flows uncontrolled to the sea, either because of location (for example, the North Coast Region) or because there is no space available in reservoirs to hold the water. However, about 100,000 af could either be stored in surface reservoirs or ponded and allowed to percolate into ground water aquifers. There may be a potential to boost these amounts of runoff and water yield by roughly another 25 percent by implementing recommended or selected forest management plans.

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Sea Water Desalination

During the 1987–92 drought, a few communities had to resort to nontraditional means of supplying water. For example, the City of Santa Barbara financed and built a desalination plant to increase the reliability of its supplies.

Sea water desalination can be a cost-effective water supply alternative for some coastal communities that have limited local supplies and are relatively far from the statewide distribution system, or communities that are concerned about water service reliability. Desalination plants in Avalon (on Catalina Island) and the City of Santa Barbara are examples of such projects. However, a major limitation for sea water desalting is its high cost, much of which is directly related to its high energy requirements. Sea water desalting plants could be designed to operate only during droughts to augment other supplies and avoid the relatively high costs during wet periods. They could also be downsized and operated continuously in conjunction with ground water, reducing ground water pumping during wet periods and providing more ground water supplies for drought periods. Chapter 11 presents a broader discussion of the potential for future desalination in California.

Recommendations

Bulletin 1, *Water Resources of California*, was published in 1951. DWR should initiate work to update and maintain this resource document to incorporate more recent hydrologic data, including 40 more years of runoff data.

Table 3-5. Major Surface Water Reservoirs in California*

Reservoir (dam)	*Hydrologic Region*	*Area (acres)*	*Capacity (1,000 af)*	*Owner*	*Year Completed*
Clear Lake	NC	24,800	527	USBR	1910
Tahoe	NL	122,000	744	USBR	1913
Clear Lake	SR	43,800	313	YCFCWCD	1914
Hetch Hetchy (O'Shaughnessy Dam)	SJ	1,970	360	SF	1923
Shaver Lake	SJ	2,180	135	SCE	1927
Almanor	SR	28,260	1,143	PG&E	1927
Bucks	SR	1,830	106	PG&E	1928
Pardee	SJ	2,130	210	EBMUD	1929
Salt Springs	SJ	980	142	PG&E	1931
El Capitan	SC	1,560	113	SD	1934
Havasu (Parker)	CD	20,400	619	USBR	1938
Matthews	SC	2,750	179	MWD	1918
Lake Crowley (Long Valley)	SL	5,280	183	LADWP	1941
Prado	SC	6,700	183	USCE	1941
Shasta	SR	29,500	4,552	USBR	1945
Millerton (Friant)	SJ	4,900	520	USBR	1947
Isabella Lake	TL	11,400	568	USCE	1953
Cachuma (Bradbury)	CC	3,090	190	USBR	1953
Thomas A. Edison	SJ	1,890	125	SCE	1954
Pine Flat	TL	5,970	1,000	USCE	1954
Folsom	SR	11,450	977	USBR	1956
Lloyd Lake (Cherry Valley)	SJ	1,540	269	SF	1956
Nacimiento	CC	5,680	340	MCWRA	1957
Berryessa (Monticello)	SR	20,700	1,600	USBR	1957
Vaquero (Twitchell)	CC	3,700	240	USBR	1958
Wishon	TL	970	128	PG&E	1958
Courtright	TL	1,630	123	PG&E	1958
Casitas	SC	2,720	254	USBR	1959
Lake Mendocino (Coyote Valley)	NC	1,960	122	USCE	1959
Mammoth Pool	SJ	1,100	123	SCE	1960
Clair Engle (Trinity)	NC	16,400	2,448	USBR	1962
Lake Kaweah (Terminus)	TL	1,940	143	USCE	1962
Black Butte	SR	4,560	144	USCE	1963
Camp Far West	SR	2,680	104	SSWD	1963
Union Valley	SR	2,870	277	SMUD	1963
Camanche	SJ	7,470	417	EBMUD	1963
Whiskeytown	SR	3,200	241	USBR	1963
New Hogan	SJ	4,410	317	USCE	1963
San Antonio	CC	5,602	335	MCWRA	1965
French Meadows (L. L. Anderson)	SR	1,420	136	PCWA	1965
Hell Hole	SR	1,250	208	PCWA	1966

Table 3-5. Major Surface Water Reservoirs in California* (Continued)

Reservoir (dam)	*Hydrologic Region*	*Area (acres)*	*Capacity (1,000 af)*	*Owner*	*Year Completed*
Lake McClure (New Exchequer)	SJ	7,150	1,024	MID	1967
San Luis	SJ	13,000	2,039	USBR	1967
Oroville	SR	15,800	3,538	DWR	1968
New Bullards Bar	SR	4,810	966	YCWA	1970
Stampede	NL	3,440	226	USBR	1970
New Don Pedro	SJ	12,960	2,030	TID-MID	1971
Castaic	SC	2,240	324	DWR	1973
Pyramid	SC	1,300	171	DWR	1973
Perris	SC	1,360	131	DWR	1973
H. V. Eastman (Buchanan)	SJ	1,780	150	USCE	1975
Indian Valley	SR	4,000	300	YCFCWCD	1976
New Melones	SJ	12,500	2,420	USBR	1979
Sonoma Lake (Warm Springs)	NC	3,600	381	USCE	1982
New Spicer Meadow	SJ	1,990	189	CCWD	1989

Reservoir Owners Listed

CCWD:	Calaveras County Water District
DWR:	California Department of Water Resources
EBMUD:	East Bay Municipal Utility District
LADWP:	Los Angeles Department of Water and Power
MCWRA:	Monterey County Water Resources Agency
MID:	Merced Irrigation District
MWD:	Metropolitan Water District of Southern California
PCWA:	Placer County Water Agency
PG&E:	Pacific Gas and Electric Company
SCE	Southern California Edison Company
SD:	City of San Diego
SF:	City and County of San Francisco
SMUD:	Sacramento Municipal Utility District
SSWD	South Sutter Water District
TID-MID:	Turlock Irrigation District and Modesto Irrigation District
USBR:	U.S. Bureau of Reclamation
USCE:	U.S. Army Corps of Engineers
YCFCWCD:	Yolo County Flood Control and Water Conservation District
YCWA:	Yuba County Water Agency

*Reservoirs with capacities exceeding 100,000 acre-feet; listed in chronological order of completion.

Ground water pumping in Yolo County. Ground water provides roughly 25 percent of the State's urban and agricultural average annual supply.

C-037721

Chapter 4

Ground Water Supplies

In an average year, about 40 percent of the urban and agricultural applied water use or over 20 percent of total applied water in California is provided by ground water extraction. In drought years, when surface supplies are reduced, ground water provides an even larger percentage of applied water. This shift from surface to ground water supplies in drought years is an indication of the sheer magnitude of ground water storage versus surface storage. Surface water and ground water are really one source of supply that originates with precipitation and runoff.

DWR's Bulletin 118, *California's Ground Water*, September 1975, identified 450 ground water basins in the state. The statewide total amount of ground water stored in these ground water basins is estimated to be about 850 million acre-feet, about 100 times the annual net ground water use in California. Probably less than half of this total, under present circumstances, is usable because:

- extraction would induce either sea water or saline ground water to intrude into the aquifer;
- the ground water in the basin is naturally too saline or of too poor a quality for economical present-day use;
- the depth to ground water makes the cost of extraction uneconomical for the potential use; or
- extraction of ground water could cause unacceptable amounts of land surface subsidence.

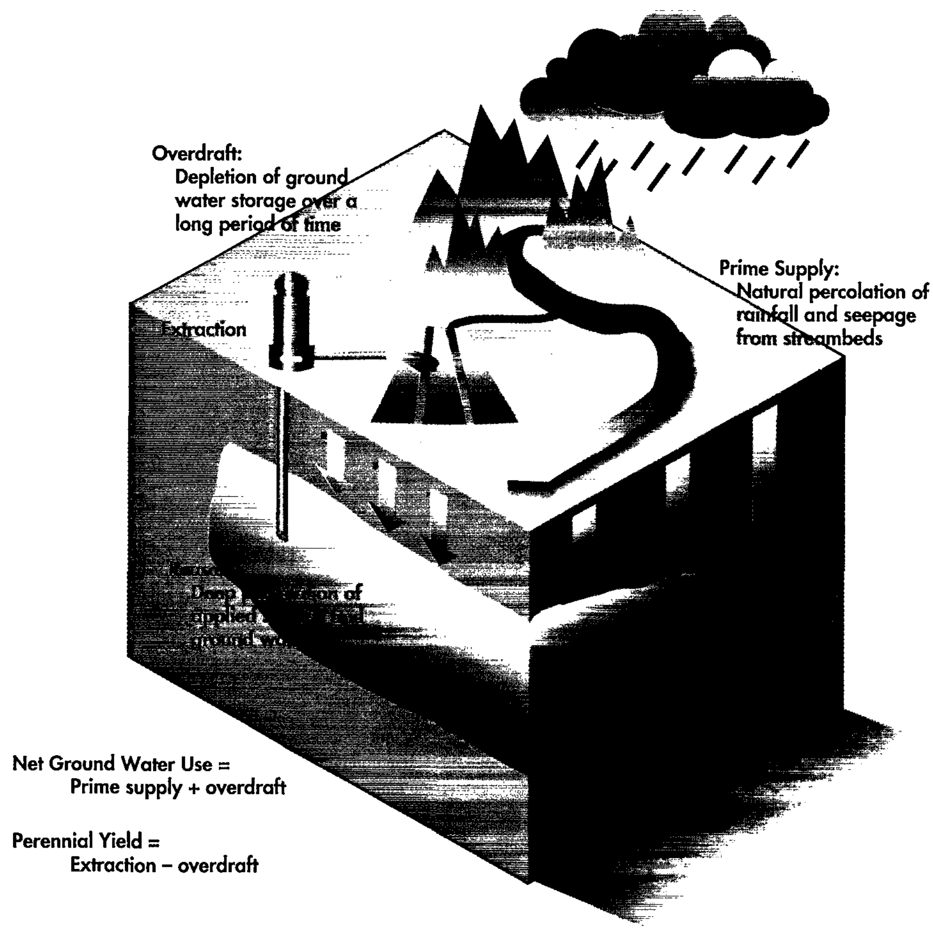
The large quantity of good quality ground water in storage makes it an extremely important component of California's total water resource that must be managed in conjunction with surface water supplies to ensure sustained availability. This chapter presents a definition of ground water and covers the history of ground water development in California, statewide ground water use, ground water overdraft, management of ground water, the effect of the 1987-92 drought on ground water, and conjunctive use.

Ground Water Defined

Ground water is subsurface water occurring in a zone of saturation. In that zone, water fills the pore spaces or openings in rock and sediments. Large basins in southern California and the Central Valley can contain thousands of vertical feet of sediments washed in over millions of years by runoff. The sediments are a randomly interfingered mixture of fine-grained material that can restrict movement of ground water and coarse-grained material that constitutes the aquifers within a zone of saturation. An aquifer is a geologic formation that stores, transmits, and yields significant quantities of water to wells and springs. Ground water also occurs in limited quantities in fractured hard rock and is an important source for domestic supplies in foothill and mountain communities. However, the following discussion will focus on the ground water in basins with abundant ground water storage and high well yields.

Ground water basins in California have been defined on the basis of geologic and hydrologic conditions in DWR Bulletin 118, *Ground Water Basins in California*, January 1980. In Bulletin 118-80, some basin boundaries were modified to reflect political or water district boundaries that constitute potential ground water management units. Figure 4-1 illustrates components of ground water use and sources of ground water recharge.

Figure 4-1. Components of Ground Water Use and Sources of Recharge



Ground Water Development

When Europeans first arrived in California, essentially all of the ground water basins in the state were full of water. Marshes existed in many parts of California and many flowing streams were supplied from overflowing ground water basins. As California settlers began to use water for crop irrigation and for industrial and domestic purposes, readily available and reliable ground water was used to augment surface water supplies.

As the amount of ground water extraction increased, ground water levels in many basins began to decline as more of the aquifer in the basin was emptied each year. The empty portion of the aquifers provided available storage space for any water that was available for recharge. Some ground water recharge was provided by direct rainfall, but most recharge resulted from infiltration of surface water runoff directly into the sediments in the bottoms of stream channels, or by infiltration of a portion of the water applied to irrigate agricultural crops.

The amount of water flowing in many streams gradually decreased as more water infiltrated into stream bottoms and recharged depleted aquifers. In some basins, the amount of ground water extracted greatly exceeded the amount of runoff available in the streambed to recharge the basins, resulting in no surface flows out of some basins. In other years when flood flows occurred, surface water would again flow down the river channels. This process continues today.

Extensive ground water use during California's early development led to establishment of vigorous agricultural and urban economies. These sectors were later able to pay the costs of developing and importing surface water by building dams and conveyance systems to meet the growing demand for water; reduce ground water overdraft; and, in some instances, increase ground water storage.

Statewide Ground Water Use

In a year of average precipitation and runoff, an estimated 15 maf of ground water is extracted and applied for agricultural, municipal, and industrial use. There is a significant amount of ground water recharge from surface water and ground water used to irrigate agricultural crops. Some of the irrigation water flowing in unlined ditches and some of the water that is applied to irrigate crops infiltrates into the soil, percolates through the root zone and recharges the ground water basins. The annual net use of ground water is ground water extraction minus deep percolation of applied water. The 1990 statewide average annual net ground water use was about 8.4 maf. The use of prime supply from ground water basins for 1990 was about 7.1 maf, and the remaining 1.3 maf was overdrafted from the basins. (*Ground water prime supply* is the long-term average annual percolation into major ground water basins from precipitation and from flows in rivers and streams.) Table 4-1 shows use of ground water (excluding overdraft) by hydrologic region.

In an average year, the amount of deep percolation from applied surface and ground water supplies that recharges the aquifers is an estimated 6.5 maf. In addition,

Table 4-1. Use of Ground Water by Hydrologic Region[1]
(thousands of acre-feet)

Hydrologic Region	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
North Coast	263	283	275	295	286	308	298	316
San Francisco Bay	100	139	126	174	160	174	165	174
Central Coast	688	762	694	769	695	776	698	781
South Coast	1,083	1,306	1,100	1,325	1,125	1,350	1,150	1,375
Sacramento River	2,496	2,865	2,463	2,985	2,426	3,033	2,491	3,038
San Joaquin River	1,098	2,145	1,135	2,202	1,156	2,227	1,161	2,252
Tulare Lake	915	3,773	918	3,758	921	3,726	926	3,758
North Lahontan	121	146	128	154	138	165	147	173
South Lahontan	221	252	220	237	226	271	258	271
Colorado River	80	80	79	79	80	80	79	79
TOTAL	7,100	11,800	7,100	12,000	7,200	12,100	7,400	12,200

(1) Average year ground water use represents use of prime supply of ground water basins. Ground water overdraft is not included.

over 7.0 maf recharges naturally from rainfall and streambed seepage. Still more water is recharged deliberately through artificial means. Statewide, the average amount of ground water extracted exceeds the average recharge by about 1.3 maf—a considerable reduction from former estimates of nearly 2 maf—and is largely the result of changes in water management. Implementation of agricultural water conservation and urban landscape conservation will decrease deep percolation of applied water, thereby reducing future ground water recharge and perennial yield of ground water basins. In areas like San Joaquin and Tulare regions, where deep percolation of applied water is a major contributor of ground water perennial yield, this process could exacerbate ground water overdraft in the future.

In wet years, when more surface water is available, less ground water is extracted, more recharge occurs, and ground water levels can recover. Conversely, in years of low runoff, such as the 1987-92 drought, much less surface water is available for recharge, and much more ground water is extracted. Ground water use also varies in different areas of the State; ground water may provide as little as a few percent or as much as 90 percent of the total applied water in an area during an average year.

Table 4-2 shows the normalized 1990 level of development for ground water. The perennial yields include the benefits of imported surface supplies that have occurred historically. In areas that rely on SWP or CVP imports from the Delta, future perennial yields may be reduced because of changes in the amount of surface water that is imported.

Estimating Perennial Yields of Ground Water Basins

Perennial yield is estimated by plotting the change in ground water level versus the amount of ground water extracted each year over a period of years that are considered to be representative of the long-term average hydrology. For this analysis, data for 13 years were plotted for each basin analyzed. A "best fit" curve was drawn and the intersection of the best fit curve with the line showing zero ground water level change indicated the current estimated perennial yield of ground water in that basin. The perennial yield is similar to long-term sustained yield, assuming there are no changes in water management practices.

The procedure probably underestimates perennial yield, or may not work, in aquifers where extraction increases the ground water gradient and induces additional recharge. The perennial yield of these aquifers would increase as extraction increased so long as recharge was equal to, or greater than, the extraction. This procedure does not take into consideration either existing or potential problems with ground water quality.

Table 4-2. Ground Water Management in California
1990 Level of Development

(All quantities are estimates and have been normalized. Only major basins in the hydrologic regions are listed.)

Basin	Extraction (ac-ft/yr)	Perennial Yield (ac-ft/yr)	Overdraft (ac-ft/yr)[6]	Usable Storage (ac-ft)	Pump Lift (est. feet)[1]	Number of Wells Monitored	Most Recent Study	Management and Status of Basin
North Coast Region								
Tule Lake	12,200	Unknown	0	Unknown	10	26		
Siskiyou Butte Valley	94,000	Unknown	0	1,300,000	70	65	USBR 1980	None; seasonal depletion of Butte Valley basalt, the unconfined aquifer
Shasta Valley	28,000	Unknown	0	Unknown	50	53	DWR 1974 USGS 1980	None
Scott River Valley	11,000	Unknown	0	300,000	Not evaluated	16	DWR 1974 USGS 1958	Part of the basin is adjudicated
Hoopa Valley	2,300	Unknown	0	9,500	Not evaluated	9	DWR 1965 USGS 1961	None
Smith River Plain	8,900	Unknown	0	75,000	50	28	DWR 1967	None; local contamination/aldicarb
Mad River Valley	25,000	Unknown	0	60,000	Not evaluated	12	DWR 1974 USGS 1959	None
Eureka Plain	9,300	Unknown	0	Unknown	30	11	DWR 1974 USGS 1975	None
Eel River Basin	32,400	Unknown	0	100,000	40	25	DWR 1974 USGS 1975	None
Covelo Round Valley	3,500	Unknown	0	150,000	Not evaluated	18	DWR 1974 USGS 1977	None
Laytonville Basin	1,000	Unknown	0	17,500	Not evaluated	7	DWR 1965 USGS 1986	None
Little Lake Valley	1,100	Unknown	0	44,000	Not evaluated	19	DWR 1965 USGS 1988	None
Klamath River Mouth Basin	600	Unknown	0	Unknown	40	5	DWR 1986	None
Prairie Creek Basin	600	Unknown	0	Unknown	Not evaluated	1		None
Redwood Creek Basin	200	Unknown	0	Unknown	Not evaluated	1		None
Humboldt Big Lagoon	1,000	Unknown	0	Unknown	Not evaluated	1	USGS 1975	None
Hayfork Basin	Unknown	Unknown	0	Unknown	Not evaluated	4		None
Mendocino County	15,738	Unknown	0	Unknown				None
San Francisco Bay Region								
Petaluma Valley	3,100	Unknown	0	Unknown	50	51		None
Napa-Sonoma Valley	11,100	Unknown	0	Unknown	50	24		None
Suisun-Fairfield Valley	4,800	Unknown	0	40,000	55	15		None

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Table 4-2. Ground Water Management in California (Continued)
1990 Level of Development
(All quantities are estimates and have been normalized.)

Basin	Extraction (ac-ft/yr)	Perennial Yield (ac-ft/yr)	Overdraft (ac-ft/yr)[6]	Usable Storage (ac-ft)	Pump Lift (est. feet)[1]	Number of Wells Monitored	Most Recent Study	Management and Status of Basin
San Francisco Bay Region, Continued								
Santa Clara Valley	150,000	Unknown	0	Unknown	50	0		Managed by Santa Clara Valley Water District; stable; some contamination; Superfund site
Livermore Valley	5,500	Unknown	0	200,000	50	0		Managed by ACFWCD, Zone 7
Marin County	2,220	Unknown	0	Unknown				None
San Mateo County	13,408	Unknown	0	Unknown				None
Central Coast Region								
Soquel Aptos	9,000	9,000	0	Unknown	Not evaluated	50	1981	Monitoring program
Pajaro Basin	64,000	53,000	11,000	600,000	Not evaluated	75	1993	Some sea water intrusion; basin management plan completed; managed by Pajaro Valley Water Management Agency
Salinas Basin	550,000	500,000	50,000	5,500,000	70	400	1992	Study in progress; sea water intrusion; managed by Monterey County Water Agency
So. Santa Clara-Hollister	75,000	75,000	0	1,800,000	230	93	1972	Monitoring program
Carmel Valley-Seaside	14,000	12,000	2,000	33,000	40	50	1993	Monitoring program
Arroyo Grande Nipomo Mesa	14,000	8,000[2]	6,000	180,500	Not evaluated	Unknown	1991	
Santa Maria Valley	129,000	66,000[3]	63,000	1,000,000	Not evaluated	Unknown	1991	Developing a management plan
Cuyama Valley	28,000	16,000[4]	12,000	400,000[5]	Not evaluated	Unknown	1986	None
San Antonio	16,400	7,400[2]	9,000	300,000	Not evaluated	Unknown	1991	None
Santa Ynez Valley	67,000	42,000[2]	25,000	362,000	Not evaluated	Unknown	1991	Developing a management plan
South Central Coast	31,400	11,400	20,000	317,000	Not evaluated	23	1991	None
Carrizo Plain	510	600[4]	0	100,000	Not evaluated	Unknown	1986	None
Upper Salinas	64,000	20,000	44,000	Unknown	Not evaluated	Unknown		None
San Luis Obispo	13,000	10,000	3,000	Unknown	Not evaluated	Unknown		None
South Coast Region								
Orange County	208,000	262,000	0	800,000	Not evaluated	150	1992	Managed by Orange County Water District; stable
Chino	145,000	145,000	0	1,200,000	Not evaluated	140	1991	Adjudicated; poor water quality in lower end of basin
San Bernardino Basin Area	232,090[7]	232,100	0	1,500,000	Not evaluated	150	1992	Adjudicated; high ground water at lower end of basin
Riverside Basin Area in San Bernardino Co.	20,390[8]	21,080[9]	0	Unknown	Not evaluated	Included in San Bernardino Basin	1992	Part of San Bernardino adjudication; stable

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Table 4-2. Ground Water Management in California (Continued)
1990 Level of Development
(All quantities are estimates and have been normalized.)

Basin	Extraction (ac-ft/yr)	Perennial Yield (ac-ft/yr)	Overdraft (ac-ft/yr)[6]	Usable Storage (ac-ft)	Pump Lift (est. feet)[1]	Number of Wells Monitored	Most Recent Study	Management and Status of Basin
South Coast Region, Continued								
Riverside Basin Area in Riverside Co.	28,550	29,630	0	Unknown	Not evaluated	Included in San Bernardino Basin	1992	Part of San Bernardino adjudication; stable
Colton Basin	9,150	Unknown	0	Unknown	Not evaluated	Included in San Bernardino Basin	1992	Part of San Bernardino adjudication; stable
Central Basin	180,000	217,380	0	1,300,000	Not evaluated	651	1992	Adjudicated; stable
West Coast Basin	60,000	64,470	0	756,000	Not evaluated	479	1992	Adjudicated; stable
San Fernando Valley	96,000	104,040	0	600,000	Not evaluated	174	1992	Adjudicated; stable; Superfund site—ground water contamination
Raymond Basin	30,000	30,620	0	400,000	Not evaluated	53	1992	Adjudicated; stable
San Gabriel	148,000	254,000	0	8,600,000	Not evaluated	393	1992	Adjudicated; stable; Superfund site—ground water contamination
Upper Ojai Valley	6,000	6,000	0	40,300	Not evaluated	79	Dec.1992	GWMA formed 10/91; stable
Fox Canyon GWMA Area	143,000	121,000	22,000	Unknown	Not evaluated	200	1992	GWMD extraction reduction ordinance; sea water reduction ordinance; sea water intrusion at coast; stable levels in some areas
Temecula Valley	25,000	Under study	Under study	206,000	Not evaluated	150	1973	Adjudicated; stable
San Juan Valley	5,000	5,000	0	9,000	Not evaluated	Unknown	1988	Limited ground water use; some sea water intrusion; stable
El Cajon Valley	500	5,000[10]	0	Unknown	Not evaluated	5	1986	Very limited ground water use; stable
Warner Valley	Unknown	Unknown	Unknown	55,000	50-200	Unknown	1973	
San Luis Ray	Unknown	Unknown	Unknown	50,000	50-100	Unknown	1973	
Sweetwater Valley	2,500	2,500[10]	0	Unknown	Not evaluated	4[10]	1986	None; stable
Otay Valley	1,000	1,000[10]	0	Unknown	Not evaluated	3[10]	1986	Some ground water use; no management; stable
Sacramento Region[11]								
Butte County	385,000	385,000[12]	0	4,300,000	100	138	DWR 1985	Water Code Section 10750
Colusa County	181,000	181,000[12]	0	4,400,000	80	95	DWR 1978	None; discussing developing a program; stable w/imported water; local drainage problems caused by high ground water
Tehama County	222,000	222,000[12]	0	4,500,000	120	150	DWR 1978 USGS WQ 1978	Concern about potential ground water export; Water Code Section 10750

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Table 4-2. Ground Water Management in California (Continued)
1990 Level of Development

(All quantities are estimates and have been normalized.)

Basin	Extraction (ac-ft/yr)	Perennial Yield (ac-ft/yr)	Overdraft (ac-ft/yr)[6]	Usable Storage (ac-ft)	Pump Lift (est. feet)[1]	Number of Wells Monitored	Most Recent Study	Management and Status of Basin
Sacramento Region[11], Continued								
Glenn County	270,000	325,000[12]	0	4,800,000	140	126	DWR 1978	Stable; Local districts are considering Water Code Section 10750 plans
Sacramento County	348,000	315,000	33,000	4,000,000	115	75	1993	Planning under Water Code Section 10750 has begun.
Western Placer County	56,000	60,000	0	1,300,000	105	90	1978	None
Yuba County	137,000	160,000	0	2,500,000	85	100	1992	Part stable; part recovering; planning under Water Code Section 10750 has begun.
Sutter County	295,000	300,000	0	5,000,000	35	150	1978	Planning under Water Code Section 10750 has begun.
Eastern Solano County	123,000	130,000	0	2,000,000	55	80	1978	Local planning has begun; stable
Yolo County	338,000	340,000	0	7,000,000	80	320	1978	Local planning has begun; stable; some subsidence
Sierra Valley	9,000	less than 9,000	Under study	Unknown	130	115	DWR 1982 with updates	Ordinance to stop overdraft in eastern portion of valley; two chronic pumping depressions
Goose Lake Basin	26,700	Unknown	0	Unknown	40	29	DWR 1982	None
Alturas Basin (Summed with Goose Lake Basin)	Unknown	Unknown	0	Unknown	140	41	DWR 1982	None
Big Valley	20,100	Unknown	0	Unknown	20	38	DWR 1982	None; Water Code Section 10750
Fall River Valley	33,100	Unknown	0	Unknown	Not evaluated	26	DWR 1982	None
Redding Basin	53,600	Unknown	0	Unknown	130	55	USGS 1983	None; Water Code Section 10750
Almanor Lake Basin	19,000	Unknown	0	Unknown	10	19	DWR 1980	None
Indian Valley	Unknown	Unknown	0	Unknown	Not evaluated	6		None
American Valley	Unknown	Unknown	0	Unknown		5		None
Mohawk Valley	1,000	Unknown	0	Unknown	Not evaluated	4		None
Chilcoot Sub-Basin	Unknown	Unknown	0	Unknown	Not evaluated	16	DWR 1983 with updates	Sierra Valley Ground Water Management District Ordinance
Upper Lake Basin[16]	8,300	4,400	Unknown	5,000	Not evaluated	21	DWR 1957 USBR 1988 1976 Lake Co.	1976 Lake Co. None; Water Code Section 10750 plan under consideration
Lower Lake Basin[16]	Unknown	800	Unknown	Unknown	Not evaluated	6	Lake Co. 1976	None
Lake County Scotts Valley[16]	9,000	2,300	Unknown	4,500	Not evaluated	13	DWR 1960 USBR 1988 Lake Co. 1976	Subsidence reported
Kelseyville Valley Basin[16]	15,300	15,000	Unknown	60,000	40	106	DWR 1960 USBR 1988 Lake Co. 1976	None

Table 4-2. Ground Water Management in California (Continued)
1990 Level of Development
(All quantities are estimates and have been normalized.)

Basin	Extraction (ac-ft/yr)	Perennial Yield (ac-ft/yr)	Overdraft (ac-ft/yr)[6]	Usable Storage (ac-ft)	Pump Lift (est. feet)[1]	Number of Wells Monitored	Most Recent Study	Management and Status of Basin
Sacramento Region[11], Continued								
High Valley Basin[16]	1,400	300	Unknown	900	50	9	Lake Co. 1976	None
Burns Valley[16]	300	800	Unknown	1,400	Not evaluated	8	DWR 1960 USGS 1955 Lake Co. 1976	None
Coyote Valley[16]	2,300	5,000	Unknown	7,000	60	12	Lake Co. 1976	Seasonal depletion of unconfined aquifer
Middletown-Collayomi Valley[16]	2,300	Unknown	Unknown	7,000	Not evaluated	16	Lake Co. 1976	Seasonal depletion of unconfined aquifer
San Joaquin Region								
Sacramento County	154,000	135,000	19,000	2,000,000	115	40 GWL	1978	Water Code Section 10750 planning has begun
San Joaquin County	830,000	760,000	70,000	6,000,000	110	600	1988	Some management
Modesto Basin	236,000	221,000	15,000	1,370,000	75	216	1982	District wells for drainage and supply
Turlock Basin	397,000	379,000	18,000	2,443,000	90	293	1982	District wells for drainage and supply
Merced Basin	568,000	540,000	28,000	4,312,000	80	272	1982	District wells for drainage and supply
Chowchilla Basin	252,000	239,000	13,000	1,043,000	150	222	1982	Small recharge operations
Madera Basin	580,000	535,000	45,000	2,814,000	160	257	1982	Small recharge operations
Delta Mendota	503,000	487,000	16,000	4,440,000	55	755	1982	Some agencies have wells for drainage and supply
Tulare Lake Region								
Kings Basin	1,699,000	1,454,000	245,000	9,275,000	130	832	1982	Some management
Tulare Lake Basin	528,000	443,000	85,000	1,500,000	250	267	1982	Some management
Kaweah Basin	746,000	701,000	45,000	3,395,000	140	642	1982	Some management
Tule Basin	565,000	500,000	65,000	1,880,000	290	403	1982	Some management
Westside Basin	201,000	171,000	30,000	Unknown	500	847	1982	None
Pleasant Valley Basin	104,000	74,000	30,000	920,000	330	133	1982	None
Kern County Basin	1,350,000	1,220,000	130,000	11,200,000	310	1,249	1982	Some management
North Lahontan Region								
Surprise Valley	44,300	Unknown	Unknown	2,000,000	160	90	DWR 1986 WL DWR 1982 WQ	Have drafted GWMD legislation; levels currently dropping
Honey Lake Valley	57,300	Unknown	Unknown	4,000,000	150	137	USGS 1991	GWMD ordinance; locally close to perennial supply
Long Valley Basin	100	Unknown	0	Unknown	80	44	DWR 1963	GWMD ordinance
Termo-Madeline Plains	21,000	Unknown	0	800,000	40	23	DWR 1963	None

Table 4-2. Ground Water Management in California (Continued)
1990 Level of Development
(All quantities are estimates and have been normalized.)

Basin	Extraction (ac-ft/yr)	Perennial Yield (ac-ft/yr)	Overdraft (ac-ft/yr)(6)	Usable Storage (ac-ft)	Pump Lift (est. feet)(1)	Number of Wells Monitored	Most Recent Study	Management and Status of Basin
North Lahontan Region, Continued								
Willow Creek Valley	4,000	Unknown	0	Unknown	Not evaluated	14	DWR 1963	Ground water management district board of directors has been appointed and is working on a ground water management plan
Secret Valley	500	Unknown	0	Unknown	Not evaluated	10	DWR 1963	None
Eagle Lake Basin	Unknown	Unknown	0	Unknown	Not evaluated	6		None
South Lahontan Region								
Owens Valley	103,000	110,000(13)	0	Unknown	Not evaluated	600	1993	Cooperative agreement between Los Angeles Department of Water and Power and Inyo Co.; stable
Death Valley	12,000	2,000	10,000	Unknown	Not evaluated	Unknown		None
Mojave River Valley	129,000	72,000(14)	57,000	4,370,000	Not evaluated	125	1993	Overdraft; adjudication in progress
Antelope Valley	26,000	58,000	0	20,000,000	Not evaluated	205	1980	Voluntary with incentives
Colorado River Region								
Warren Valley	2,740(15)	900(14)	1,840	160,000	200-400	24	1992-1993	Adjudicated; overdraft
Coachella Valley	85,000	33,000	52,000	3,600,000	Not evaluated	Unknown	1980	Locally managed, overdrafted
Chuckwalla	27,000	4,000	23,000	Unknown	Not evaluated	Unknown		None

(1) Pump lifts vary considerably within a basin. This number represents an approximate mean.
(2) Per DWR Coastal Branch EIR and addendum 1991.
(3) Estimated at San Luis Obispo Co. 13.5 TAF/Y, Santa Barbara Co. 52.5 TAF/Y. From DWR Coastal Branch EIR, 1991.
(4) Per San Luis Obispo County Master Water Plan update, March 1986.
(5) Useable storage above sea level estimated at 100,000 AF. Total usable storage estimated at 400,000 AF.
(6) Overdraft is indicated as zero when the exact amount of perennial yield is unknown but is greater than current extraction.
(7) 70,034 AF are extracted in San Bernardino Co. and used in Riverside Co. (DAU 98).
(8) 8,719 AF are used in San Bernardino Co. (6,715 AF pumped by San Bernardino Co. entities, remainder pumped by Riverside Co. entities).
(9) Adjudicated rights of Riverside Co. entities only.
(10) Estimates based on DWR report "San Diego Ground Water Studies, Phase IV, June 1988."
(11) The Sacramento Valley is defined as one basin in Bulletin 118-80. Ground water data are shown in this basin by county to reflect management units that have been defined since Bulletin 118-80 was published.
(12) Perennial yield is estimated because most basins in the Sacramento Valley have not been stressed.
(13) LADWP and Inyo Co. Agreement limits long-term average ground water pumping to 110,000 AF/Y and the annual maximum pumping to approximately 200,000 AF/Y. Source: Mono Basin EIR May 1993
(14) From Mojave Water Agency Notice of *Preparation for Regional Water Management Plan*, May 1993.
(15) Warren Valley Basin Water Master Report, 1992-93.
(16) Ground water data for this basin have been obtained from four studies published between 1957 and 1990. Additional data and evaluation are necessary to provide more accurate values of annual extraction, perennial yield, overdraft, and usable storage.

Ground Water Overdraft

In areas where water demands exceed available surface water and sustainable ground water supplies, a portion of the difference between supply and demand is often made up by extracting ground water, thereby decreasing the amount of ground water

Evaluation of Ground Water Overdraft in the San Joaquin Valley

Ground water overdraft for the San Joaquin Valley was evaluated for each planning subarea (PSA) using two independent methodologies: the specific yield method and the water balance method. The specific yield method examines changes in ground water storage over a long period; the water balance method is based on the balancing of water supplies and demands for each PSA.

In computing overdraft using the specific yield method, ground water level measurements from 1970 through spring 1983 were used. This period was chosen for the following reasons:

- The total water supplies and demands for this period were nearly the same as the 1990 normalized supplies and demands.
- On average, the local water supplies and deliveries during 1970-82 were quite similar to the long-term average supplies and deliveries. This minimizes the need to correct for any unusual ground water recharge and pumping. Also, local stream runoff during 1970-82 was very close to the long-term average runoff (about 102 percent of the long-term average). Ground water overdraft was computed based on 100-percent average local runoff and deliveries.
- The years preceding the ground water level measurements in 1970 and spring 1983 were both wet years and quite similar. This similarity reduces the potential for significant differences in ground water recharge during unlike years. Such an occurrence would complicate overdraft computations using the specific yield method.

The impact of subsidence on water level measurements and the loss of ground water storage were evaluated using pre-1970 subsidence rates. More recent, but limited, data from a few locations along the California Aqueduct were also used.

For the water balance method, the long-term average local and imported water supplies were tabulated, along with the long-term average annual natural percolation to ground water tables. These amounts were then compared to the normalized water demand for each PSA. Ground water overdraft was computed as the difference between water supplies and demands.

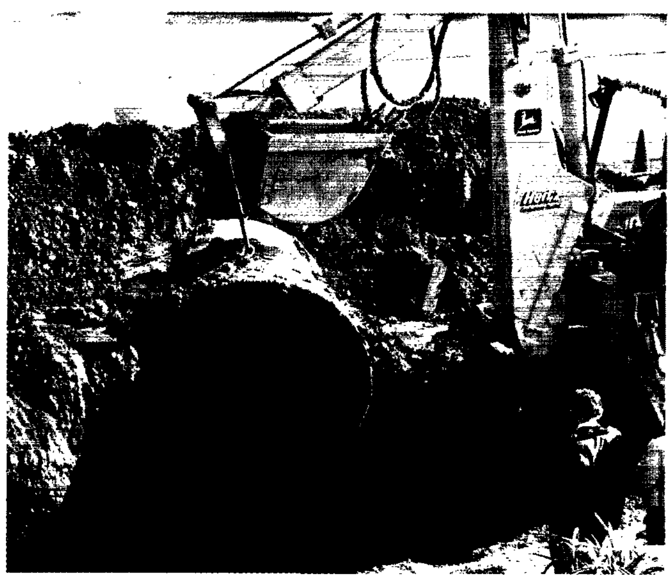
The two methodologies produced similar ground water overdraft computations for most of the PSAs in the San Joaquin Valley. One notable exception is the Kings-Kaweah-Tule Rivers PSA, where the specific yield method produced significantly smaller overdraft than did the water balance method. An extensive investigation was done to understand the reason for such a difference; however, no specific reason for the large difference could be found. Actual ground water overdraft in the Kings-Kaweah-Tule Rivers PSA is probably somewhere between the values produced by the two methodologies. For this PSA, the California Water Plan Update used the average of the ground water overdraft values computed using the two different methods.

Ground water quality degradation is another factor that must be considered when computing overdraft. Ground water overdraft in a basin may induce the subsurface movement of poor-quality water into higher-quality water. The resultant quality degradation may reduce the usable storage of a ground water basin. This adverse effect of ground water overdraft was evaluated and included in the ground water overdraft computations for the California Water Plan Update.

in storage in those basins. Where the ground water extraction is in excess of inflow to the ground water basin over a period of time, the difference provides an estimate of overdraft. Such a period of time must be long enough to produce a record that, when averaged, approximates the long-term average hydrologic conditions for the basin. Bulletin 118-80 defines "overdraft" as the condition of a ground water basin where the amount of water extracted exceeds the amount of ground water recharging the basin "over a period of time." It also defines "critical condition of overdraft" as water management practices that "would probably result in significant adverse overdraft-related environmental, social, or economic effects." Water quality degradation and land subsidence are given as examples of two such adverse effects. Table 4-3 shows 1990 estimated ground water overdraft by hydrologic region.

During the 1987-92 drought, ground water, where available, was extracted to make up for reductions in surface water deliveries. The result was that ground water levels and the amount of ground water in storage declined considerably. Such a decline is not considered overdraft, rather it is considered as removal of ground water from storage, similar to removal of water from a surface reservoir. In the past, such declines have been reversed during wet years when surface water reservoirs refilled and ground water aquifers were recharged.

Ground water quality degradation reduces usable ground water storage in ground water basins. Ground water overdraft in a basin can produce a gradient that induces movement of water from adjacent areas. If the adjacent areas contain poor quality water, degradation can occur in the basin. There is a west-to-east water gradient in the San Joaquin valley from Merced County to Kern County. Poor quality ground water moves eastward along this gradient, displacing good quality ground water in the trough of the valley. The total dissolved solids in the west side of the valley generally range from 2,000 to 7,000 milligrams per liter, the east side water from 300 to 700 milligrams per liter. This adverse effect of overdraft and possible degradation of ground water quality in the San Joaquin Valley has been evaluated and included in ground water overdraft estimates.



In Sacramento, California, a gasoline tank suspected of leaking is being removed to protect ground water quality. Until recently, most types of underground chemical storage tanks were constructed in a way that allowed the tanks to leak contaminants into the soil. SWRCB now manages a program to control contamination from underground tanks.

In the short term, those areas of California that rely on Delta exports for all or a portion of their supplies face great uncertainty in terms of water supply reliability due to the uncertain outcome of a number of actions undertaken to protect aquatic species in the Delta. For example, in 1993, an above-normal runoff year, environmental restrictions limited CVP deliveries to 50 percent of contracted supply for federal water service contractors from Tracy to Kettleman City. Because ground water is used to replace much of the shortfall in surface water supplies, limitations on Delta exports will

Table 4-3. Ground Water Overdraft by Hydrologic Region
(thousands of acre-feet)

Region	*1990*
North Coast	0
San Francisco Bay	0
Central Coast	240
South Coast	20
Sacramento River	30
San Joaquin	210
Tulare Lake	650
North Lahontan	0
South Lahontan	70
Colorado River	80
STATEWIDE	1,300

increase ground water overdraft in the San Joaquin River and Tulare Lake regions, and in other regions receiving a portion of their supplies from the Delta.

The ground water basins in small coastal areas of the Central Coast Region have limited storage capacity. During drought periods, water levels in most of these basins sometimes decline to a point where ground water basins are not usable. However, during wet periods, most of these basins recover, thus making evaluation of overdraft or perennial yields difficult. Overdraft amounts shown for the Central Coast Region were estimated by reviewing previous studies and could be overestimated. In addition, the Central Coast presently receives USBR water through San Felipe and will soon receive SWP water through the Coastal Branch of the California Aqueduct. These imported supplies could reduce overdraft in the region. A more comprehensive study of the ground water use in this region is needed to more accurately estimate the overdraft.

Estimated overdraft amounts are based on *overdraft* being defined as the amount of ground water extracted for the 1990 level of development that is in excess of the current perennial yield. "Current perennial yield" is the amount of ground water that can be extracted without lowering ground water levels over the long-term. Perennial yield in basins where there is hydraulic continuity between surface and ground water depends in part on the amount of extraction that occurs. Perennial yield can increase as extraction increases, as long as the annual amount of recharge is equal to, or greater than, the amount of extraction. Extraction at a level that exceeds the perennial yield for a short period does not result in an overdraft condition. In basins with an adequate ground water supply, increased extraction may establish a new hydrologic equilibrium with a new perennial yield. The establishment of a new and higher perennial yield requires that adequate recharge be induced. The methods used to estimate perennial yield and ground water overdraft assume that the amount of ground water extracted for the 1990 level of development is the amount of extraction that has taken place, or could take place, without lowering ground water levels over a long period of time. These estimates must include evaluation of the existing water management program in the basin.

Changes in surface water deliveries will undoubtedly change the perennial yield and overdraft conditions in the future. For example, delivery of surplus surface water supplies from the SWP and CVP will probably occur much less frequently in the future.

Such decreases in delivery of surface water will probably decrease perennial yields in basins that receive SWP and CVP water.

Sea Water Intrusion

Along some parts of the coast, declining ground water levels allow sea water to intrude into fresh water aquifers. Los Angeles County operates sea water intrusion barrier projects in West Basin and Dominguez Gap. Los Angeles and Orange counties jointly operate a sea water intrusion barrier in Los Alamitos Gap, which straddles the border between the two counties. In most of these barriers, water from water recycling facilities or from MWDSC imported deliveries is injected and flows down gradient in both directions—toward the ocean as well as inland where it mixes with ground water in the aquifer and can be extracted by irrigation and municipal wells. In some basins, a sea water intrusion barrier may be a cost-effective management tool that would allow greater use of the basin's ground water storage capacity.

In Salinas Valley, sea water intrusion was occurring before the drought began. During the drought, the rate of intrusion accelerated because of decreased ground water recharge and increased ground water extraction. Monterey County Water Resources Agency has formulated long-term plans to construct and operate facilities to substitute surface water for ground water to alleviate the sea water intrusion problem. The SWRCB is putting pressure on the Agency to start action immediately to stop the intrusion, which is now almost 5 miles inland and threatens to contaminate municipal wells in Salinas. MCWRA is dealing with overdraft and sea water intrusion in the coastal areas of the Salinas Basin and is in the process of preparing the Salinas River Basin Management Plan. Under this plan, MCWRA will screen management alternatives for preparation of an EIR/EIS. The agency has also adopted eight ordinances including requiring the metering of all wells with a discharge size greater than three inches, agricultural and urban conservation measures, establishing upper pumping limits, and ground water management charges with penalties for use exceeding the pumping limits. Sea water intrusion is also occurring in the area of the Pájaro River. Pájaro Valley Water Management Agency and the City of Watsonville are formulating plans to address the problems in that area.

In Ventura County, elevated chloride levels have been measured in much of the Oxnard Plain since the 1950s. Recent studies have concluded that there are three sources of chloride: sea water intrusion in a relatively small area; a larger area into which saline water has migrated from adjacent marine formations; and leakage of chloride from an upper perched aquifer through failed well casings into an underlying aquifer. The sea water does not appear to be moving inland. Local agencies are developing programs to address the migration of saline water and the wells that have been improperly destroyed. Fox Canyon Ground Water Management Agency, United Water Conservation District, and City of Ventura are all formulating plans to address the problems in that area.

Subsidence

In some parts of California, ground water extraction has caused subsidence of the land surface. Accurate prediction of subsidence is generally not possible with our present level of knowledge or current data about the extent and properties of aquifer sediments in subsidence areas. In some areas subsidence occurs when ground water levels decline below a certain level. Data collected from six extensometers in Westlands Water District indicate that subsidence occurred in 1990, 1991, and 1992, with the highest amount of subsidence occurring in 1991. Land subsidence can change canal gradients, damage buildings, and require repair of other structures. In some instances, local water management agencies may determine that a certain amount of land subsidence is allowable as a part of their ground water management program.

In areas where ground water extraction is proceeding or where such programs are planned, the potential for subsidence should be evaluated. Water managers may wish to include extensometer and land surface surveying if subsidence is a real potential.

Ground Water Quality

A change in ground water gradient may accelerate movement of contaminants toward water-producing wells. (See Chapter 5 for an explanation of contaminant movement and levels.) This accelerated movement of contaminants may be particularly true where ground water levels have been lowered significantly because of increased extraction during droughts. However, a ground water monitoring program for water levels and water quality is necessary to evaluate such changes.

Management of Ground Water Resources

Ground water basin management is defined as: protection of natural recharge and use of intentional recharge; planned variation in amount and location of extraction over time; use of ground water storage conjunctively with surface water from local and imported sources; and, protection and planned maintenance of ground water quality. If the basin is managed to achieve these goals, ground water overdraft will be reduced and water supplies of good quality will be sustainable.

Initial use of ground water in California considered only one aspect—building a well and extracting ground water. It was only when ground water levels began to decline, or landowners could not extract enough water from their wells, that consideration was given to the second aspect of ground water use—recharge. In contrast, no one would think of building a dam for water supply purposes before first identifying and quantifying a source of water to fill the reservoir behind the dam. Water managers in many areas where ground water was depleted realized that action was required and requested legislation to provide authority to manage the ground water basins.

The type of management structure and the extent of management of ground water basins in California vary considerably. In part, this variety arose because ground water was treated as a property right while surface water was treated under a complex system of riparian and appropriative rights. The result is that ground water is regulated both by statute and by case law from court decisions. As might be imagined, the combination of the two makes for great complexity in managing this resource.

Management of ground water in California has generally been considered a local responsibility. This view is strongly held by landowners and has been upheld by the Legislature (in a number of statutes that have established local ground water agencies) and by the courts (in decisions). State agencies have encouraged local agencies to develop effective ground water management programs to maximize their overall water supply and to avoid lengthy and expensive lawsuits resulting in adjudicated basins. The end result of either local agency ground water management programs or adjudication may be similar. Effective management can be achieved through either method.

Thirteen ground water basins have been adjudicated and are operated in accordance with court settlements. A fourteenth watershed has been adjudicated in federal court, but water users are not limited in their ground water extraction.

The California Water Code provides for management and distribution of surface water and in many instances provides some limited authority to deal with ground water through a number of types of local water agencies and districts, formed either by general or special legislation. Nine ground water management agencies have been authorized by the State Legislature. These agencies can enact ordinances affecting ground water extraction, establish zones of benefits, and charge a ground water extraction fee or levy taxes for actions that benefit the extractors. "Zone of benefit" means an area, including but not limited to, subbasins within a district which will benefit from planning, studies, or any management program undertaken by that district in a manner different from other areas or subbasins within the district (Water Code, Appendix 119-322 and 135-833).

Many water agencies have statutory authority from the Legislature to levy charges for ground water extraction when it is shown that the surface water conveyed to the area recharges the aquifer, thereby benefiting the ground water extractors. Not all of these agencies have exercised that authority. Some of those that have are Orange County Water District, Rosedale–Rio Bravo Water Storage District, Santa Clara Valley Water District, Monterey Peninsula Water Management District, and recently, Monterey County Water Resources Agency.

Such charges are colloquially called a "pump tax," although the term "water replenishment assessment" is used in the Water Code. The water replenishment assessment may consist of a water charge, a general assessment, a replenishment assessment, or a combination of two or more of the above.

In 1992, the Water Code was amended (Water Code Section 10750, et seq.) to provide authority and define procedures to allow certain local agencies to produce and implement a ground water management plan. To date, more than 40 local agencies have expressed interest in using that section of the Water Code provision to adopt a ground water management program. A number of those agencies have adopted resolutions of intent in accordance with Water Code Section 10750 to adopt a ground water management plan. Adoption of such a resolution allows the agency two years to adopt a plan. If no plan is adopted in that time frame, the agency must start the process over again. The Water Code encourages coordination between agencies in the same basin. Early indications are that some agencies that share a basin are interested in formulating their own plans, while some other agencies that share a basin intend to develop one coordinated cooperative plan for the entire basin. In addition, several mutual water companies have expressed interest in developing ground water management plans.

Procedure for Adopting a Ground Water Management Plan in Accordance with Water Code Section 10750

- ❑ Hold noticed public hearing on Resolution of Intention to Draft a Ground Water Management Plan.
- ❑ Write and publish a Resolution of Intention to Adopt a Ground Water Management Plan.
- ❑ Prepare a draft ground water management plan within two years or restart the process.
- ❑ After the draft plan is completed, hold a second noticed hearing.
- ❑ Landowners affected by the plan may file protests.
- ❑ If a majority protest occurs (representing more than 50 percent of the assessed valuation of the land), the ground water management plan shall not be adopted.
- ❑ If a majority protest does not occur, the plan may be adopted.
- ❑ A local agency may fix and collect fees and assessments for ground water management costs associated with the implementation of the ground water management plan, if such authority is approved by a majority of votes cast in a popular election.

However, such local entities are not included in the legal definition of "local agency" but can sign Memorandums of Understanding with local agencies to develop a ground water management plan under Section 10750.

Adjudicated Basins

In 13 adjudicated ground water basins, ground water extraction is regulated by a watermaster that has been appointed by the court. Twelve of these adjudicated basins are in Southern California and one is in Northern California (Figure 4-2). Ground water extraction in each of these basins was adjudicated with concern only for ground water *quantity*. Ground water *quality* was not a part of the original court decisions.

The amount of ground water that each well owner can extract is determined by the court decision and is based on the amount of ground water that is available each year, as determined by the watermaster. While each court decision may be slightly different, the goal is to avoid ground water overdraft by providing sustainable yield. Adjudication of these ground water basins has generally resulted in additional imports of surface water supplies to make up for reduced extraction.

The thirteen adjudicated ground water basins and watermasters in California are:

Los Angeles County

- Central Basin: DWR
- West Coast Basin: DWR
- Upper Los Angeles River Area: an individual specified in the court decision
- Raymond Basin: management board appointed by the court, DWR staff
- Main San Gabriel Basin: nine-director board

Kern County

- Cummings Basin: Tehachapi–Cummings Water District
- Tehachapi Basin: Tehachapi–Cummings Water District

San Bernardino County

- Warren Valley: Hi–Desert Water District
- San Bernardino Basin Area: one representative each from Western Municipal Water District of Riverside County and San Bernardino Valley Municipal Water District
- Cucamonga Basin: not yet appointed
- Mojave River Basin: Mojave Water Agency

Riverside and San Bernardino Counties

- Chino Basin: Chino Basin Municipal Water District

Siskiyou County

- Scott River Stream System: two local irrigation districts

Ground water and surface water in a fourteenth basin, Santa Margarita River Watershed in Riverside and San Diego Counties, has also been adjudicated by the federal court. Water users are required by the court decision to report to the court-appointed water master the amount of surface water they divert from the river, canals, or ditches, and the amount of ground water they extract from the aquifer. However, the amount of water they are entitled to is not limited by the decision.

Figure 4-2. Locations of Adjudicated Ground Water Basins

C-037739

C-037739

The watermaster for Main San Gabriel Basin in Southern California has since returned to the court and obtained approval of regulations to control extraction for the purpose of protecting ground water quality. Ground water underflow from Puente Basin, a part of Main San Gabriel Basin, was addressed in a court decision separate from the Main San Gabriel adjudication. The court named two individuals to act in the capacity of watermaster.

Ground Water Management Agencies

The Legislature has enacted several specific statutes establishing ground water management agencies that can enact ordinances to regulate the amount of ground water that is extracted and limit its place of use within the district's boundaries. Nine ground water management agencies have been formed by such special legislation. (See Figure 4-3 for their locations.)

While these agencies have the authority to pass ordinances, such ordinances limiting extraction are not popular with landowners within the agency's boundaries. In addition, the funding for studies that are required to establish zones of benefit to ensure equitable assessments has not been readily available. Therefore, it is not yet clear whether these agencies will become viable and effective at managing ground water in a manner that conserves quantity and preserves good quality.

The nine ground water management agencies are:

Lassen County

- *Honey Lake Valley Ground Water Management District:* Board of Directors not yet appointed.
- *Willow Creek Valley Ground Water Management District:* Board of Directors has been appointed.

Lassen and Sierra Counties

- *Long Valley Ground Water Management District:* has adopted an ordinance that requires a permit to export ground water outside the basin.

Sierra County

- *Sierra Valley Ground Water Management District:* has called for voluntary landowner cooperation to reduce extraction and submit records on extraction.

Mono County

- *Mono County Tri-Valley Ground Water Management Agency:* is establishing a network of monitoring wells.

Mendocino County

- *Mendocino City Community Services District:* requires well owners to record their extraction.

Santa Cruz County

- *Pájaro Valley Water Management Agency:* is dealing with sea water intrusion and high nitrates in ground water. A basin management plan that will address ground water extraction and surface water imports has been completed, and fees on extraction have been assessed.

Ventura County

- *Fox Canyon Ground Water Management Agency:* has adopted an ordinance prohibiting export of ground water outside the lateral boundaries of the aquifer.

Figure 4-3. Locations of Ground Water Management Districts or Agencies

C-037741

C-037741

- *Ojai Basin Ground Water Management Agency:* Board of Directors recently appointed. Water quality of the basins is good, with the apparent exception of localized, elevated nitrate ion concentrations. Further data collection over a wider geographic area will be required to identify the severity of the problem.

Water Districts with a Pump Charge

A number of water districts have obtained Legislative authority to levy a pump charge on wells that extract a certain amount of ground water. Two of these districts manage their surface water and ground water in a conjunctive operation. The third is moving in the same direction. These water districts are:

Orange County

- *Orange County Water District*

Santa Clara County

- *Santa Clara Valley Water District*

Monterey County

- *Monterey Peninsula Water Management District*

Other Districts

Desert Water Agency and Coachella Valley Water District are authorized to levy replenishment assessment charges to fund certain programs. Many other flood control and water conservation districts, water storage districts, water replenishment districts, irrigation districts, community services districts, water agencies, and others either manage surface water only or may be involved in some minor ground water management. Management of surface water can affect the timing and location of ground water extraction, use, and recharge.

Effect of the Drought on Ground Water

The large amount of ground water available in California's ground water basins provided a reliable source of water during the 1987-92 drought. During previous droughts ground water extraction has provided as much as 60 percent of urban and agricultural applied water statewide. The following sections describe the effects of drought on ground water levels and storage and potential impacts from overdrafting basins.

Ground Water Levels and Storage

The depth of water in wells in California's ground water basins differs considerably among basins and even in different parts of the same basin. The water levels are affected by many factors, including the amount of recharge that has occurred in previous years, the ratio of surface water to ground water used, the total number and location of wells extracting ground water from the basin, the amount of ground water that flows out of the basin, and the total amount of ground water extracted from the basin.

While smaller surface water reservoirs can refill in a single year if the precipitation and runoff are above normal, it can take several years of above normal precipitation before ground water levels in a basin recover to pre-drought levels. The increase in ground water storage is a function of the amounts of pumping and natural recharge, as well as the contribution to recharge from applied irrigation water or direct recharge operations.

The amount of ground water currently in storage in the San Joaquin Valley has decreased considerably since 1987 because of the low amount of recharge from spring

1987 through spring 1992, combined with the large amount of ground water that was extracted during that time.

As a result of the drought, it was expected that the extraction of ground water through spring 1992 would be much higher than normal. In Kern County, more ground water was extracted between spring 1991 and spring 1992 than during the previous four years. However, the amount of ground water extracted between spring 1991 and spring 1992 in Stanislaus, Merced, Madera, Fresno, Tulare, and Kings counties was significantly less than the amount of ground water extracted during the previous few years. The reasons for the unexpected decreases in ground water extractions are still being investigated. Possible factors include rainfall variations, fallowed land, changes in crops, a high intensity–long duration rainfall in some parts of California in March 1991, and somewhat better runoff amounts in 1991 than in 1990 for the southern Sierra Nevada. The change in ground water in storage in the San Joaquin Valley is shown in Figure 4-4.

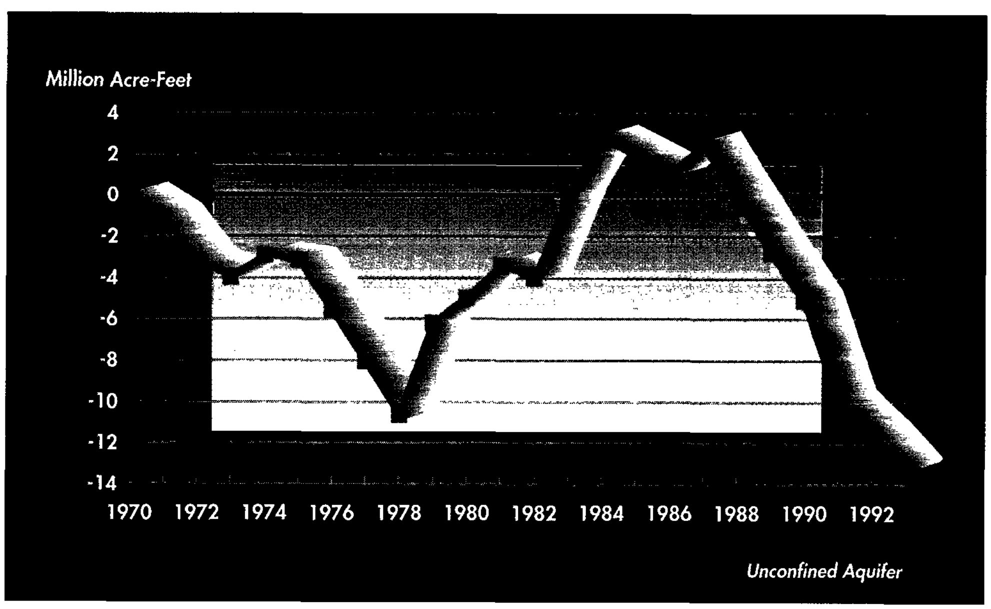
Ground water levels in most basins rose as a result of ground water recharge from the storms that passed over California in December 1992 and January through March 1993 which provided large amounts of precipitation and runoff. Such recovery of ground water levels in many basins occurs during wet years, primarily as a result of two factors:

- Surface water is available and is the primary source of irrigation water, thus reducing extraction of ground water.
- In many areas, about 15 to 20 percent of the water applied for irrigation moves past the root zone and results in recharge of the ground water basin. The amount of such deep percolation varies in different areas.

The net change in the amount of ground water storage during summer 1993 will not be known until spring 1994 water level measurements are evaluated. The spring measurements of any year reflect events that occurred during the previous 12 months. Thus, spring 1993 water level measurements reflect the recharge that occurred in winter 1992–93 and the extraction that took place in summer 1992.

In the Sacramento Valley, ground water levels and storage did not decline significantly in Glenn and Colusa counties during the 1987–92 drought. In Butte and

Figure 4-4. Cumulative Change in Ground Water Storage San Joaquin Valley



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Tehama counties, ground water levels declined, but some remained higher than they were after the 1976–77 drought. The change in ground water storage in the Sacramento Valley is shown in Figure 4-5.

In coastal areas, some ground water basins have limited storage. Ground water levels in such basins are often lowered to near critical levels each fall, thus making evaluation of overdraft or sustainable yield difficult. These basins require relatively little time to recharge to return to a full condition. As a result, ground water levels in these basins can rise rapidly due to high rainfall such as occurred in March 1991, December 1992, and January through March 1993.

The ground water basins surrounding Clear Lake in Lake County also have limited storage capacity. Each year ground water levels in these shallow ground water basins decline to a point where ground water quality starts to deteriorate. But each winter these basins normally refill. In these areas of limited storage, ground water has very little capacity to support additional development.

Ground water levels in the adjudicated basins and managed basins in Southern California vary. In Main San Gabriel Basin and the coastal plain of Orange County, water levels are about at the middle of their court–approved operating range. Ground water levels in San Fernando Valley range from high to low, depending on location. Levels in Central and West Coast Basins are fairly high.

Wells and Ground Water Use

Reduction of surface supplies during drought increases ground water extraction while recharge remains significantly below normal. As ground water levels decline, more energy is required to lift the water to the surface, adding to the cost of water for urban and agricultural use. Furthermore, existing wells often become unusable, requiring deepening or, in some cases, replacement of wells. (Figure 4-6 shows the number of well completion reports filed, by year, from 1974 through 1992.) Upon the return of normal or above normal precipitation, such as that occurring in late 1992 and 1993, ground water extraction decreases markedly as surface water becomes more available. The shift from using ground water to using surface water results in significant ground water recharge.

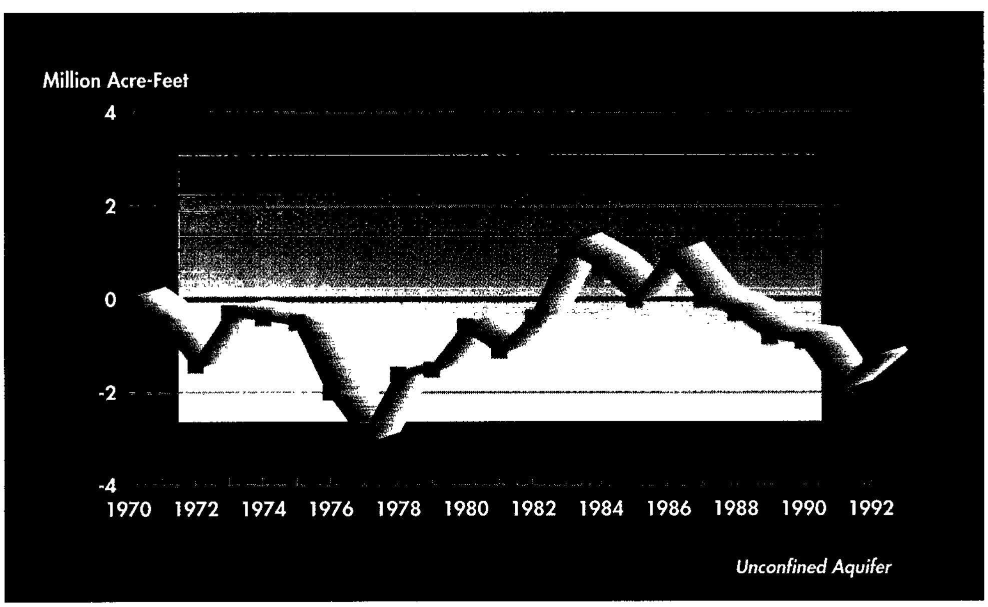
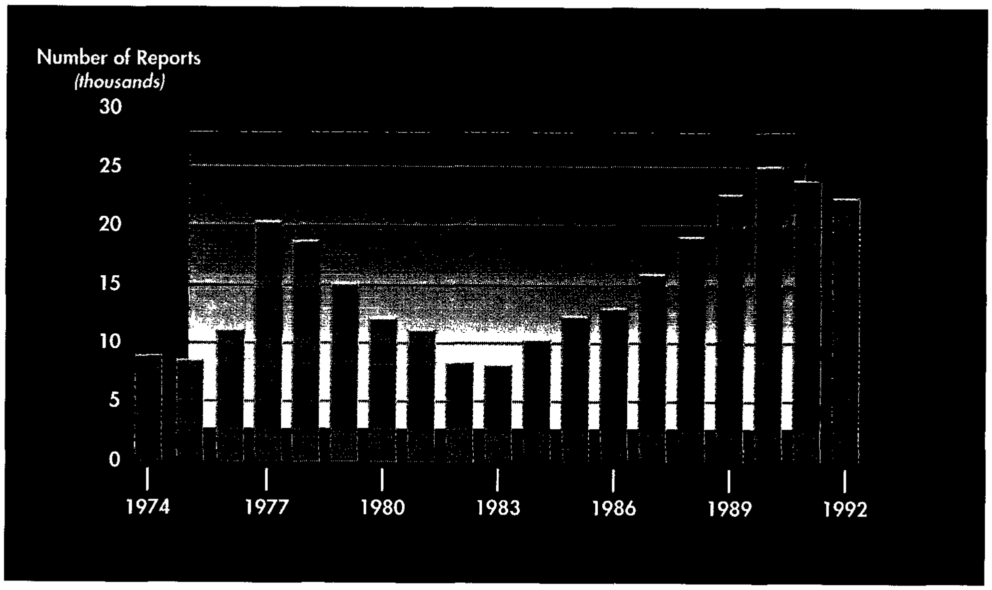


Figure 4-5. Cumulative Change in Ground Water Storage Sacramento Valley

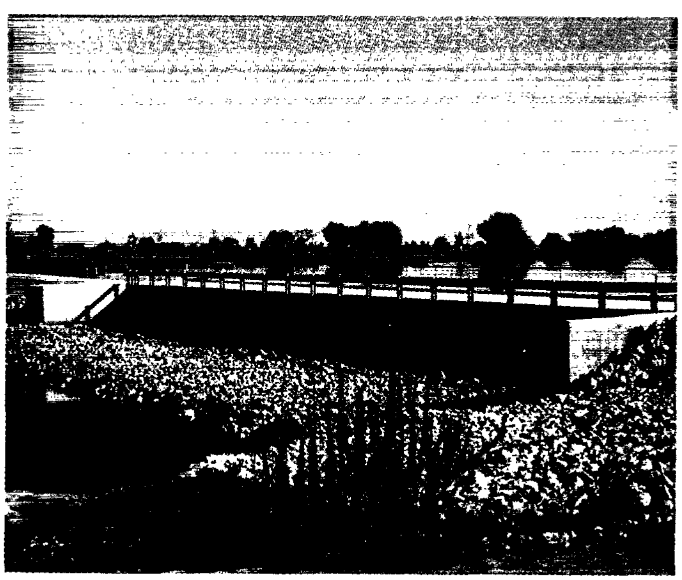
Figure 4-6. Annual Well Completion Reports (thousands)



The number of new wells reported as drilled during the 1987–92 drought peaked in 1990 after increasing during the earlier years of the drought. Slightly over one–third of the wells reported in 1990 were monitoring wells and many others were either replacement or deepening of existing wells.

Conjunctive Use

Conjunctive use is the operation of a ground water basin in coordination with a surface water system to increase total water supply availability, thus improving the overall reliability of supplies. The basin is recharged, both directly and indirectly, in years of above-average precipitation so that ground water can be extracted in years of below-average precipitation when surface water supplies are below normal. In some instances conjunctive use is employed for annual regulation of supplies. These programs involve recharge with surface water or reclaimed water supplies and same–year extraction for use. Aquifer storage and recovery programs are a good example of conjunctive use. Following is a discussion of effective conjunctive use programs and the types of programs in–place today.



Ground water recharge in the City of Bakersfield. The city operates a 2,800-acre recharge facility southwest of Bakersfield where the city and some local water agencies recharge surplus Kern River water, and occasionally SWP and Friant-Kern Canal water. The water is withdrawn in drier times.

Conjunctive use programs are designed to increase the total usable water supply by jointly managing surface and ground water supplies as a single source. As such, they are widespread in California but differ greatly in their intensity and degree of planning. Management can vary from recharging a limited amount of sporadically available surface water to a comprehensive management program that coordinates surface water use, delivery, recharge, and ground water extraction and use.

In the future, carefully planned conjunctive use will increase and become more comprehensive because of the need for more water and the generally higher cost of new surface water facilities. Conjunctive use programs generally promise to be less costly than new traditional surface water projects because they increase the efficiency of water supply systems and cause fewer negative environmental impacts than new surface water reservoirs.

Various local agencies have implemented programs and coordinated with other agencies to recharge surface water, when it is available, so that ground water will be stored in the aquifer until it is needed. These agencies have effectively secured or implemented some or all of the following components of a conjunctive use program:

- a source of surface water
- identified usable storage capacity in the aquifer
- identified possible re-regulation of surface water reservoirs
- recharge facilities
- extraction facilities
- distribution facilities for surface water and ground water
- monitoring wells for quantity and quality
- a means of financing and sharing the costs among the beneficiaries

Carefully planned and implemented conjunctive use programs can be developed without causing significant adverse impacts. However, the effect of such programs on native vegetation and wetland habitat, fish and wildlife resources, third parties, land subsidence, and degradation of water quality in the aquifer must be evaluated. Phreatophytic vegetation may be stressed when ground water levels are lowered because less water is available in root zones. Similar processes can also affect wetlands. Potential adverse effects on third parties include lowering of ground water levels below the bottom of wells, or raising ground water levels so that local flooding occurs. Subsidence caused by extraction of ground water can affect canals, wells, buildings, tanks, bridges, and levees that require costly repair. Ground water quality can be degraded if ground water gradients induce movement of lower quality water into the aquifer.

Interest in conjunctive use as a means of augmenting supplies that may then be exported to areas outside the basin has led to questions about the feasibility and legal complexity of water transfers involving ground water. Both the State Water Code and the recently passed *Central Valley Project Improvement Act of 1992* specify that any water transfers under their respective jurisdictions cause "no significant long-term adverse impact on ground water conditions in the transferor's service area." The CVPIA requirement will affect water districts that receive water from the CVP and seek to transfer either surface or ground water.

Conjunctive Use Programs

A broad range of conjunctive use activities have been undertaken in California, although many of them probably were not thought of as conjunctive use when developed. The range of conjunctive use activities in California is illustrated by the following partial list of examples of programs in place today.

Alameda County Water District. The district is located near the mouth of the Niles Cone area of Alameda County, adjacent to San Francisco Bay. Historically, extraction of ground water from the basin lowered ground water levels and allowed sea water from the Bay to intrude. In response, the district has developed an extensive program to recharge local supplies from Alameda Creek and imported supplies from other surface sources.

Kern County. In Kern County, a mix of local, regional, and State conjunctive use projects are operating or are under development. The Kern County Ground Water Basin is in overdraft although changes in storage vary considerably depending on the surface water availability to local agencies. Several districts have responded by building and operating recharge projects that take advantage of imported and/or local surface water when available. For example, the Rosedale-Rio Bravo Water Storage District purchases surface water from three sources and recharges ground water via Goose Lake Slough. Essentially all water use within the district is supplied by ground water.

On an interregional scale, the Arvin-Edison Water Storage District and the Metropolitan Water District of Southern California are developing a cooperative water banking project. In this complex program, Arvin-Edison will provide MWDSC water during dry years from Arvin-Edison's CVP supply and will replace this water by pumping ground water from a basin previously recharged with surface water supplies made available by MWDSC from its SWP supply. (See Chapter 11 for more details about the program.)

The Department of Water Resources, in cooperation with local agencies in Kern County, is developing the Kern Water Bank project to augment the supplies available to SWP contractors in drought years. (See Chapter 11 for more details.)

Metropolitan Water District of Southern California. In 1989, MWDSC implemented a seasonal ground water storage program utilizing both direct and in lieu recharge and storage in local ground water basins to increase emergency supply and provide carryover storage for droughts.

Orange County Water District. This district has one of the most elaborate conjunctive use programs. It purchases imported surface water from MWDSC for ground water recharge, manages runoff and recycled water in the Santa Ana River, manages extraction from the basin, operates a sea water intrusion barrier, is contemplating additional barriers to allow use of even more ground water storage capacity, is improving ground water quality in areas where it has been degraded, and recharges a large quantity of recycled water.

Santa Clara Valley Water District. The district provides and operates treatment and distribution facilities for surface water imported from the SWP and the CVP and recharge sites for local surface and imported water supplies. The basin is managed to provide an adequate supply of ground water annually, eliminate land subsidence, and provide carryover ground water storage as a buffer against dry years when local and imported surface water supplies are reduced.

South Sutter Water District. Irrigated agriculture in this area has relied on ground water for many years. As a result, a regional ground water depression developed as local pumping exceeded recharge. In response to the declining ground water levels, the district constructed Camp Far West reservoir on the Bear River to develop a partial surface water supply for the district. This has been successful in reducing demand on the ground water basin, which has since recovered. During extended dry periods, increased ground water use causes ground water levels to fall. The district is investigating ways to further develop the conjunctive use potential of the basin.

United Water Conservation District. The district captures winter runoff in Lake Piru and releases the water each fall down the Santa Clara River to replenish the ground water basins along the river. These basins have limited storage capacity and are generally operated on an annual cycle that largely uses the entire capacity. United also operates two spreading areas to recharge the Oxnard Plain ground water basin in coastal Ventura County.

Westlands Water District. The early development of irrigated agriculture in Westlands was based on extraction of ground water from a deep, confined aquifer system. This development resulted in extensive land subsidence. To alleviate this problem, Westlands obtained an imported surface water supply from the CVP that allowed it to largely eliminate ground water pumping in most years. In years with deficient surface water supplies, water users revert to ground water pumping.

Yolo County Flood Control and Water Conservation District. This district operates Clear Lake and Indian Valley reservoirs to provide a surface water supply for irrigated agriculture. The district does not have the capability of extracting ground water, but local farmers maintain the capability to largely offset dry year surface water shortages by pumping additional ground water. The district has undertaken a program to artificially recharge ground water in its service area.

Prospects for the Future

In the future, conjunctive use is expected to increase and become more comprehensive if California's water needs are to be met in a cost effective and efficient manner while resolving conflicts with other resources. Conjunctive use programs generally promise to be less costly than new traditional surface water projects as they increase the efficiency of existing systems and are expected to cause fewer negative environmental impacts.

Recommendations

The State should encourage efforts to develop ground water management programs at the local and regional levels and to remove legal, institutional, financial, and other barriers that limit conjunctive use of ground water basins. The programs should be focused on solutions to clearly identified problems, such as overdraft, and natural and human-caused contamination so as to optimize the use of surface and ground water resources. Specific recommendations are as follows:

1. Local agencies should adopt programs for ground water management with the following goals:

    a. Identify and protect major natural recharge areas. Develop managed recharge programs where feasible.

    b. Optimize use of ground water storage conjunctively with surface water from local sources, including storage of recycled water and imported sources.

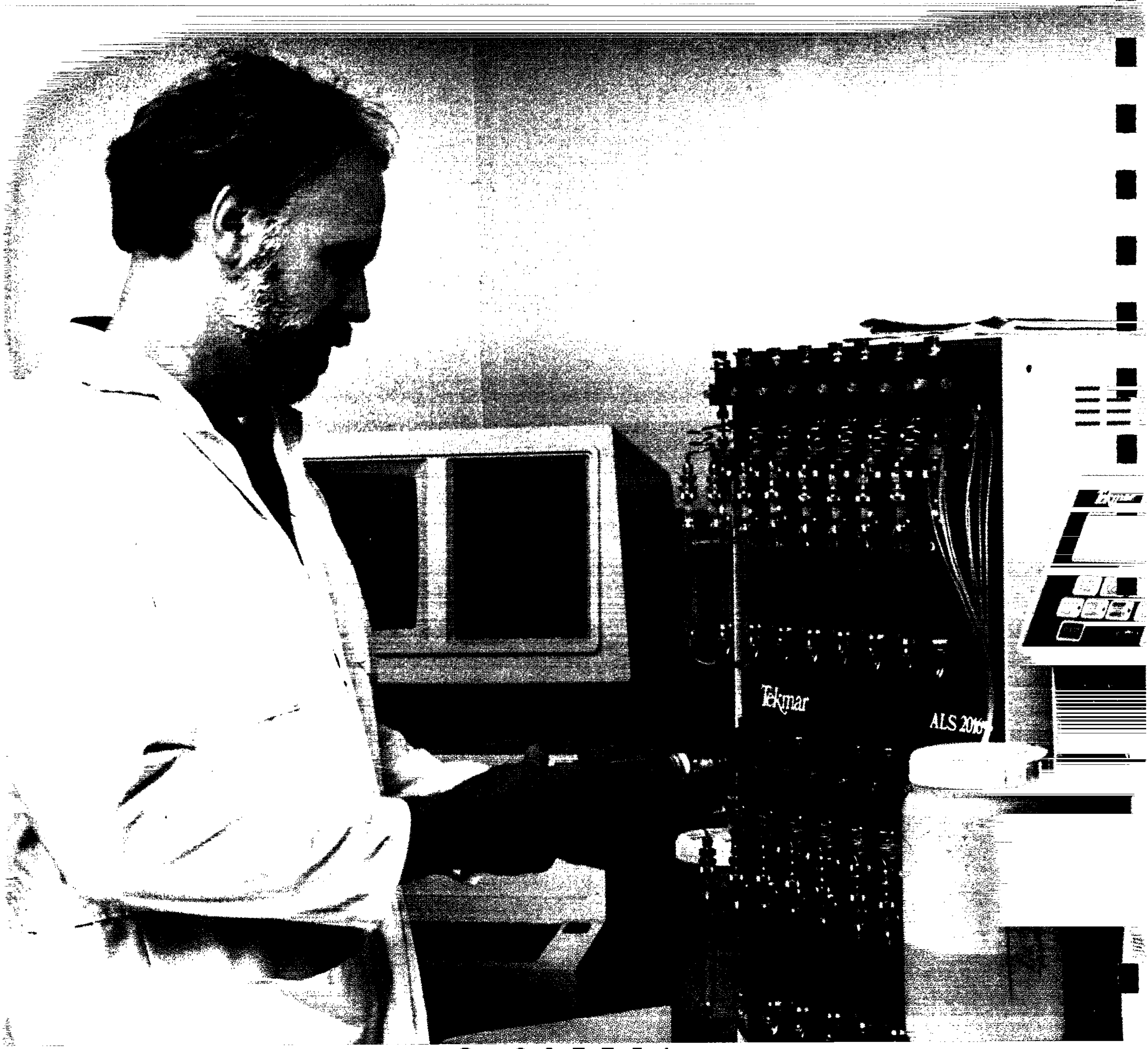
    c. Increase monitoring of ground water quality so that the State can improve its ability to assess and respond to water degradation problems. Report trends in the chemical contents of ground water.

    d. Develop ground water basin management plans that not only manage supply, but also address overdraft, increasing salinity, chemical contamination, and subsidence.

e. Adopt and implement a public education program to ensure that citizens understand the importance of ground water and steps they can take to protect and enhance their water supply.

2. Continuing use of overdraft as a source of supply is not sustainable and must be addressed in State and local water management plans. Options for addressing the management of overdraft will be strongly influenced by economic factors that must be considered in such plans.

Water samples are tested at DWR's Bryte Lab, located on the west side of the Sacramento River. The sensitive electronic equipment used at this lab can detect one part chemical in one billion parts water.



Chapter 5

Water Quality

Water has numerous uses, and each use has certain quality requirements that vary widely. The quality needed to wash cars, for example, is lower than that required to irrigate orchards or make computer chips. In some cases, different water uses have conflicting quality requirements; water temperatures ideal for crop irrigation may be unsuitable for fish spawning, for instance.

Quality considerations have a direct bearing on the quantity of water available for use. Water quality parameters, such as temperature, turbidity, and oxygen, mineral, dissolved metal, and nutrient content, all affect the usability of water and, therefore, affect the total available quantity for specific uses. Although California has access to a virtually unlimited supply of ocean water, it is too salty for most uses without costly treatment. Water management must consider quality to determine the overall availability of water supplies in California. The pressures of a steadily growing population, additional requirements for water to meet environmental needs, and potentially more frequent water shortages pose serious water management and risk management problems for California.

This chapter describes factors affecting water quality as they relate to California water management as well as the regulatory mechanisms designed to correct and prevent quality problems affecting water supply and beneficial uses. Because the Sacramento–San Joaquin Delta and its tributaries, the Sacramento and San Joaquin rivers, are key to California's water supply picture, water quality issues affecting these water bodies are discussed. The Colorado River and California's ground water supplies are also of great importance, and quality issues affecting these supply sources are also addressed.

California's burgeoning population and limited water supplies require maximum water use efficiency. Water recycling and reuse are important means of stretching supplies; therefore, quality considerations pertaining to recycling and reuse are reviewed. Finally, an overview of some costs of poor water quality makes the importance of water quality most obvious.

Overview of Water Quality in California

When water falls as snow or rain, it contains very low concentrations of inorganic minerals and organic compounds, a result of the natural purification processes of evaporation and precipitation. Once on the ground, much of the water evaporates or is used by vegetation, some percolates into the ground, and much of the remainder flows toward the Pacific Ocean. On its way, it is subject to many influences.

Mineralization and Eutrophication

As water passes over and through soils, it picks up soluble minerals (salts) present in the soils because of natural processes, such as geologic weathering. As the water

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passes through a watershed and is used for various purposes, concentrations of dissolved minerals and salts in the water increase, a process called mineralization. As Sierra Nevada streams flow into the valleys, they typically pick up 20 to 50 milligrams per liter (parts per million) of dissolved minerals, which is equivalent to about 50 to 140 pounds of salts per acre-foot. (An acre-foot of water with total dissolved solids of 736 mg/L contains one ton of salt, which is typical of Colorado River water.)

The increased concentration of minerals also results from municipal water uses. Water passing through a typical municipal water supply system, including waste water treatment before discharge, typically increases in salt load by about 150 to 200 milligrams per liter. Industrial usage usually contributes to mineralization, which can be less than or far greater than that resulting from municipal use, depending on the industry.

In California, a major source of mineralization is sea water intrusion into the Sacramento-San Joaquin Delta, the export location for much of California's water supply. Sea water intrusion in the Delta elevates the salinity (particularly the ions of concern, sodium, chloride, and bromide) of fresh water, worsening the quality of Delta water. For example, during the period 1986 to 1992, the average concentration of dissolved solids (salt) in the lower Sacramento River was 108 mg/L (parts per million). In the lower San Joaquin River, the average was 519 mg/L, and at H.O. Banks Pumping Plant, the southern Delta export location of the State Water Project, the average was 310 mg/L.

The San Joaquin River contributes about 16 percent, on average, of the fresh water inflow to the Delta, and the Sacramento River contributes about 80 percent. On average, Delta influences are responsible for elevating the salt concentration at Banks Pumping Plant about 150 mg/L above the salt concentrations present in the fresh water inflows to the Delta. Considerable improvement in mineral quality could, therefore, be achieved if the influence of the Delta (sea water intrusion, island drainage, municipal waste water) could be eliminated.

The bromides contributed by sea water intrusion are of particular concern because they contribute to formation of harmful disinfection byproducts during drinking water treatment processes. Control of upstream flow by reservoirs greatly enhances the capability to repel sea water from the Delta. Without these facilities, the entire Delta would frequently contain salty water from San Francisco Bay and the Pacific Ocean.

Eutrophication results from addition of nutrients (nitrogen, phosphorus, and many necessary micronutrients) to surface waters. In the presence of sunlight, algae and other microscopic organisms are able to use the available nutrients to increase their populations.

Slightly or moderately eutrophic water, such as the water in Delta channels, can be healthful and support a complex web of plant and animal life. However, water containing large populations of microorganisms is undesirable for drinking water and other needs. Some types of microorganisms can produce compounds that, while not directly injurious to human health, may cause the water to smell and taste bad and can be costly and extremely difficult to remove.

Toxic Pollutants

Elements such as nickel, silver, chromium, lead, copper, zinc, cadmium, mercury, arsenic, and selenium can be toxic or carcinogenic at certain concentrations.

Many of these are present in California's water due to runoff from abandoned mining operations, such as the Iron Mountain Mine on the Spring Creek tributary of the upper Sacramento River. A large percentage of the heavy metals toxic to aquatic life in the Sacramento River is thought to be from abandoned mines in the upper watershed.

High concentrations of iron and other minerals in drainage from the abandoned Iron Mountain Mine affect water quality in Spring Creek and the Sacramento River.

Pathogens

Many people think water from the mountains is pure and preferable for drinking. They are often unaware that even in pristine waters, there may be disease-causing organisms. Protozoans are microscopic organisms; some types of protozoans live in the bodies of warm-blooded animals and can cause disease in humans who drink water shared with these animals. *Giardia lamblia* is common in mountain-dwelling mammals. Giardiasis is a disease in humans which comes from this organism. *Cryptosporidium* is another pathogenic organism found in drinking water supplies as a result of contamination by mammals.

In April 1993, between 200,000 to 400,000 persons in Milwaukee, Wisconsin became ill of cryptosporidiosis, the disease resulting from the presence of *Cryptosporidium* in their water supply. This outbreak presents a striking example of the importance of maintaining the quality of source waters. Even well-operated water treatment facilities can be overwhelmed when the quality of the source water is erratic.

Federal and State Surface Water Treatment Rules, effective in June 1993, require that all surface waters supplied for drinking receive filtration, high level disinfection, or both, to inactivate or remove viruses and protozoan cysts such as *Giardia* and *Cryptosporidium*. However, not all disease-causing viruses, bacteria, and protozoan cysts are destroyed in conventional drinking water treatment processes, and these may grow after discharge to waterways. Some urban water agencies routinely find *Giardia* and other protozoan cysts in water used to wash their treatment plant filters, even after rigorous disinfection that kills all other microorganisms. The cost of constructing new filtration facilities to meet the new regulation can be quite high. San Francisco, for example, has not previously filtered its water supplies, but may have to as a result of this regulation.

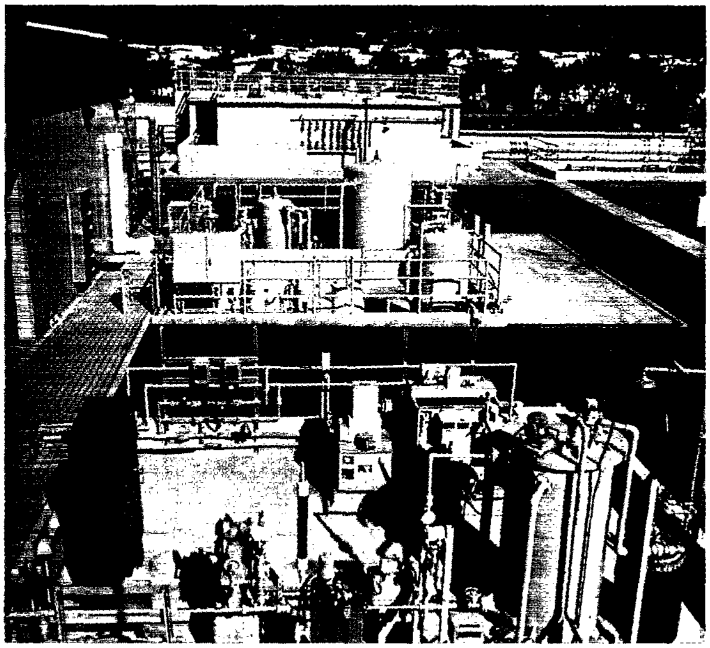
Disinfection Byproducts

In its journey to the sea, water dissolves organic compounds present in the soil as a result of plant decay. This organic material includes humic and fulvic acids, and other organic compounds. High levels of these compounds can be present in drainage from wooded or heavily vegetated areas and from soils high in organic content, such as the peat soils which are present in parts of the Delta and other places in California.

Disinfectant chemicals are applied to drinking water to kill pathogenic organisms. Chemicals such as chlorine, which are capable of efficiently killing such organisms, are highly reactive and can cause unwanted chemical reactions to occur. Trihalomethanes are a class of synthetic organic chemicals produced in drinking water when chlorine, used as a disinfectant, comes into contact with naturally occurring organic material dissolved in the water. Where present, bromide (a type of salt found in sea water) enters the reaction to produce bromine-containing trihalomethane compounds.

The organic matter and salts in Delta waters are by themselves not harmful and only become so when they undergo reaction during water treatment. However, trihalomethanes are suspected of causing cancer in humans. Maximum Contaminant Levels of trihalomethanes in drinking water have been established by the U.S. Environmental Protection Agency and California Department of Health Services, in accordance with the federal and State Safe Drinking Water laws. The current MCL for THMs in drinking water is 0.10 mg/L. The regulations establishing the MCLs are being reviewed, and the stricter standard of 0.08 mg/L is expected to be promulgated. Revisions to the federal regulations are to be proposed in 1994.

The Metropolitan Water District of Southern California uses ozone to disinfect water at its ozonation plant in LaVerne, California. MWDSC supplies 2.5 million acre-feet annually to 16 million water users.



There are less notorious disinfection byproducts, also produced in drinking water, that may cause adverse health effects. The U.S. EPA and the World Health Organization have identified disinfection byproducts of potentially more serious human health concern than trihalomethanes. One of these is bromate, formed during ozone disinfection of waters containing bromide. Drinking water regulations for disinfection byproducts such as bromate are expected to be included in the regulations to be proposed in 1994.

Ozone is a powerful oxidant widely used for drinking water disinfection. Its advantages are that it is a very strong oxidizer that efficiently kills pathogens, destroys tastes and odors, and minimizes production of trihalomethanes and unwanted byproducts. The problem of bromide in Delta water has serious implications for California and is discussed in the *Sacramento-San Joaquin Delta Water Quality* section of this chapter.

Agricultural Pollutants

Agricultural pollutants are generally of the nonpoint variety, meaning their sources are usually diffuse and are not readily subject to control. (By comparison, point sources are more identifiable and generally more sub-ject to control, such as a pipe discharging to a water body.) Agricultural drainage may contain chemical residues, toxic elements, salts, nutrients, and elevated concentrations of chemicals which produce disinfection byproducts in drinking water. In addition, protozoan cysts from dairies and ranches can enter waterways through agricultural drainage systems. Sediments resulting from land tillage can pollute waterways, obstructing water flow and affecting the survival and reproduction of fish and other aquatic organisms. (For a discussion of a specific agricultural drainage problem, see the section titled *San Joaquin Valley Drainage Program* in Chapter 2.)

Urban Pollutants

In urban areas, water quality is influenced by nonpoint sources of pollution such as recreational activities, drainage from industrial sites, runoff from streets and highways, discharges from other land surfaces, and aerial deposition. In California, storm water runoff, a major source of nonpoint pollution, is regulated by SWRCB on behalf of the U.S. EPA. (See *Water Quality Protection in* Chapter 2 for more information.)

Industrial production and municipal activities produce a number of substances that end up in municipal and industrial waste water discharges (point sources of pollution). In California, discharge of untreated sewage into the environment is not permitted. The National Pollution Discharge Elimination System regulates point discharges of waste water into the nation's waterways. Under this system, California treats waste water to render it free of certain disease-carrying organisms and reduce its environmental impact.

Most of the industries in California discharge to a publicly-owned waste water treatment plant and only indirectly to the environment. These industries are required to provide pre-treatment of their industrial waste prior to its discharge to the municipal waste water treatment plant. Like municipal discharges, industrial discharges are subject to regulation through the NPDES. Industries discharging directly into the environment are required to have an NPDES permit.

Waste water treatment facilities operated under the NPDES have, in general, been successful in maintaining the quality of California's water bodies; however, the discharge permits do not regulate all constituents that may cause adverse impacts. For example, the discharge of organic materials which contribute to trihalomethanes in drinking water is not regulated. Nor does the NPDES guarantee elimination of protozoan cysts, which are harder to inactivate (disinfect) than most other waterborne pathogens and are capable of causing disease. In addition, permitted discharges include nitrogen compounds that can be harmful to aquatic life, cause unwanted growths of algae in surface water bodies, and force downstream drinking water facilities to increase their use of chlorine.

Synthetic chemicals (manufactured by humans) are very widespread. Unfortunately, some waste water treatment plant processes do not completely remove all synthetic chemicals that can be present in the water. Depending on the processes used, some treatment plants may remove most of these compounds, while others are not able to do as well. As a result, some synthetic organic chemicals, especially from agricultural and industrial waste water, are emitted into California's waterways through treatment plant discharges.

Other Pollutants

There are a number of other sources of water pollution. Mining activities (previously mentioned in connection with toxic pollutants) can be a major source of acids and toxic metals. In some rural areas of California, use of septic tanks has resulted in bacterial contamination and nutrient pollution of ground water resources. The best solution to this problem has been installation of sewer collection and treatment facilities.

Not all sources of pollution are caused by humans. Soil erosion can result from such natural phenomena as earthquakes, landslides, and forest fires. During wet periods, eroded soils cause turbidity in the water which can seriously impact aquatic organisms and adversely affect drinking water treatment processes. Wildlife can also add nutrients to water bodies, and can host some types of waterborne disease organisms.

Table 5-1 is adapted from the report *Drinking Water into the 21st Century*, published in January 1993 by the Office of Drinking Water, Department of Health Services. This table summarizes threats to water quality within California.

Drinking Water Regulations and Human Health

Currently, there are State and federal regulations for a variety of physical, chemical, and microbiologic constituents in drinking water, including pesticides and other agricultural chemicals, trihalomethanes, arsenic, selenium, radionuclides (such as radium), nitrates, and toxic metals, as well as treatment and disinfection requirements for bacteria, viruses, *Giardia*, and other pathogens. Standards for a total of 83 individual drinking water constituents will soon be in place under the mandates of the 1986 federal Safe Drinking Water Act amendments. (See Tables 5-2 and 5-3.) This far-reaching act will likely be amended again in 1994. No reduction in the number or scope of drinking water standards is expected; the trend has been towards regulation of increasing numbers of constituents and lowering acceptable concentrations.

The trend toward ever more numerous and restrictive drinking water regulations is associated with rapidly escalating complexity and costs of all aspects of drinking water supply. Previously, treatment processes were deemed sufficiently robust to permit a large degree of variation in source water quality; this is no longer the case. Under current regulations, it is necessary to operate a very finely tuned treatment system to provide adequate disinfection while minimizing unwanted chemical byproducts. Significant variations in source water quality can upset this fine balance, potentially resulting in health risks to the population.

The need to modify and add processes to control new categories of chemicals and provide improved disinfection can result in greatly increased capital and operational expenditures. Municipal water agencies in California are facing the prospect of significant rate increases to recoup these expenditures.

Clearly, the trend toward ever more stringent drinking water regulations is a factor that will have large repercussions for the water industry in the State, as the cost of control measures is felt by the consumers. There is even some concern developing over whether the complex new regulations will actually improve protection of human health.

Meeting Water Quality Standards

SWRCB has promulgated the Inland Surface Waters Plan that establishes quality criteria for pollutant levels in California's fresh water. The Coastal Bays and Estuaries Plan establishes quality criteria for protection of the estuarine waters of California. These criteria are embodied in water quality control plans for each of California's water basins, as required under provisions of the federal Clean Water Act. Water quality control plans, commonly known as Basin Plans, establish specific water quality objectives

Table 5-1. Threats to Water Quality

Source of Contamination	*Contaminant*	*Typical Sites*
Natural (occur statewide)	Dissolved minerals	Mineral deposits, mineralized waters, hot springs, sea water intrusion
	Asbestos	Mine tailings, serpentine formations
	Hydrogen-sulfide	Subsurface organic deposits, such as Delta Islands and San Joaquin Valley trough
	Radon	Most geologic formations
Commercial Businesses	Gasoline	Service stations' underground storage tanks
	Solvents	Dry cleaners, machine shops
	Toxic metals	Photo processors, laboratories, metal plating works
Municipal	Microbial agents, nutrients, and miscellaneous liquid wastes	Bacteria and virus contaminants from a variety of sources such as sewage discharges and storm water runoff; contributions from industrial dischargers, households, and septic tanks
Industrial	VOCs, industrial solvents, toxic metals, acids	Electronics manufacturing, metal fabricating and plating, transporters, storage facilities, hazardous waste disposal
	Pesticides and herbicides	Chemical formulating plants
	Wood preservatives	Pressure treating power poles, wood pilings, railroad ties
Solid waste disposal	Solvents, pesticides, toxic metals, organics, petroleum wastes, and microbial agents	Disposal sites located statewide receive waste from a variety of industries, municipal solid wastes, wasted petroleum products, household waste
Agricultural	Pesticides (herbicides, fumigants, fungicides), fertilizers, concentrated mineral salts, microbial agents	Irrigated farm runoff, ag chemical applications, fertilizer usage, chemical storage at farms and applicators' air strips, agricultural produce packing sheds and processing plants, meat processing plants, dairies, and feed lots
Disasters	Solvents, petroleum products, microbial agents, other hazardous materials	Earthquake-caused pipeline and storage tank failures and damage to sewage treatment and containment facilities; major spills of hazardous materials; flood water contamination of storage reservoirs and ground water sources

Adapted from *Drinking Water into the 21st Century—Safe Drinking Water Plan for California*, A Report to the Legislature, California Department of Health Services, Office of Drinking Water, January 1993, p. 38.

for individual bodies of water. The Basin Plans are master planning documents intended to guide efforts to maintain and restore the quality of California's waters.

SWRCB also established specific water quality objectives to protect the uses of water in the Sacramento-San Joaquin Delta. Most of the Delta water quality objectives relate to salinity. The SWP and federal CVP are required to release sufficient fresh water to meet these Delta salinity standards. Chapter 10 contains a more detailed discussion of Delta water quality standards.

Federal and State drinking water standards have been adopted to protect the health of consumers. The California Department of Health Services Office of Drinking Water promulgates and enforces State standards and enforces federal standards. Most

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Table 5-2. Contaminants Regulated Under the Federal Safe Drinking Water Act
August, 1993

1,1-Dichloroethylene	cis-1,2-Dichloroethylene	Nickel
1,1,1-Trichloroethane	Copper	Nitrate
1,1,2-Trichloroethane	Cyanide	Oxamyl
1,2-Dibromo-3-chloropropane (DBCP)	Dalapon	Pentachlorophenol
1,2-Dichlorobenzene	Dichloromethane	Phthalates
1,2-Dichloroethane	Dinoseb	Picloram
1,2-Dichloroethylene	Diquat	Polychlorinated biphenyls (PCBs)
1,2-Dichloropropane	Endothall	Polynuclear Aromatic Hydrocarbons (PAHs)
1,2,4-Trichlorobenzene	Endrin	Radium 226
1,4-Dichlorobenzene	Epichlorohydrin	Radium 228
2,3,7,8-TCDD (Dioxin)	Ethylbenzene	Selenium
2,4-Dichlorophenoxyacetic acid (2,4-D)	Ethylene dibromide (EDB)	Silver
2,4,5-TP (Silvex)	Flouride	Simazine
Acrylamide	Giardia lamblia	Styrene
Adipates	Glyphosate	Sulfate
Alachlor	Gross alpha particles activities	Tetrachloroethylene
Antimony	Gross beta particles activities	Thallium
Arsenic	Heptachlor	Toluene
Asbestos	Heptachlor epoxide	Total coliforms
Atrazine	Heterotrophic bacteria	Total trihalomethane
Barium	Hexachlorobenzene	Toxaphene
Benzene	Hexachlorocyclopentadiene	trans-1,2-Dichloroethylene
Berylium	Lead	Trichloroethylene
Cadmium	Legionella	Turbidity
Carbofuran	Lindane	Vinyl chloride
Carbon tetrachloride	Mercury	Viruses
Chlordane	Methoxychlor	Xylenes (total)
Chromium	Monochlorobenzene	

Compiled and updated from *Status of Contaminants Regulated Under the Safe Drinking Water Act*, U.S. Environmental Protection Agency, April 1991.

drinking water quality standards are met by California's municipal drinking water utilities. However, some drinking water regulatory activities may conflict. For example, concern over surviving pathogens spurred a rule requiring more rigorous disinfection. At the same time, there is considerable regulatory concern over trihalomethanes and other disinfection byproducts, resulting from disinfection of drinking water with chlorine. The problem is that if disinfection is made more rigorous, disinfection byproduct formation is increased. Additionally, poorer quality source waters with elevated concentrations of organic precursors and bromides further complicate the problem of reliably meeting standards for disinfection while meeting standards for disinfection byproducts.

The regulatory community will have to carefully balance the benefits and risks associated with pursuing the goals of efficient disinfection and reduced disinfection byproducts. One essential corollary action will be to make any source water quality improvements that are feasible.

The U.S. Environmental Protection Agency estimates the annual nationwide cost of treating drinking water to meet existing and new standards will be $36 million a year in the early 1990s, $539 million annually by 1994, and will rise to $830 million, as a result of the need to make long-term capital investments, before stabilizing at $500

Table 5-3. Proposed Contaminants to be Regulated Under the Federal Safe Drinking Water Act
August 1993

1,1-Dichloroethane	Bromomethane	Isophorone
1,1,1,2-Tetrachloroethane	Chloral hydrate	Lactofen/Acifluorfen
1,1,2,2-Tetrachloroethane	Chloramine	Manganese
1,2,3-Trichloropropane	Chlorate	Methomyl
2,4/2,6-Dinitrotoluene	Chlorine	Methyl ethyl ketone (MEK)
4-Nitrophenol	Chlorine dioxide	Methyl isobutyl ketone (MIBK)
Acrylonitrile	Chlorite	Methyl tertiary butyl ether (MTBE)
Aldehydes	Chloroform	Metolachlor
Aldicarb	Chloropicrin	Metribuzin
Aldicarb sulfone	cis/trans-1,3-Dichloropropene (Telone)	Molybdenum
Aldicarb sulfoxide	Cyanazine	Naphthalene
Aluminum	Cyanogen chloride	Pentachlorophenol
Bentazon	Dacthal (DCPA)	Prometron
Boron	Dibromochloromethane	Radon
Bromacil	Dicamba	Trifluralin
Bromate	Ethylene thiourea (ETU)	Uranium
Bromodichloromethane	Hexachlorobutadiene	Vanadium
Bromoform	Iodate	Zinc

Compiled and updated from Status of Contaminants Regulated Under the Safe Drinking Water Act, U.S. Environmental Protection Agency, April 1991.

million a year by the year 2000. These estimates demonstrate that major costs will result from meeting the new standards.

According to data published in *Drinking Water into the 21st Century*, the current annual cost-per-service connection for drinking water ranges from about $250 for large systems to about $312 for very small systems. The added cost to implement new drinking water regulations already promulgated will range from $16 for large systems to $205 for very small systems. Additional proposed regulations may increase these costs from $115 for large systems up to $450 for very small systems. These estimates demonstrate that small water systems will be disproportionately affected by the new regulations. Alternatives for mitigating this impact are being studied.

Careful watershed surveys, followed by long-term monitoring and management plans, are the best tools to define and cope with mineralization, eutrophication, toxic metals and other chemicals, pathogens, and disinfection byproduct precursors. In response to new drinking water regulations, California water utilities began a series of surveys in 1990 in preparation for development of watershed management plans. These plans will provide a better definition of other, especially diffuse, pollutant sources. The California Urban Water Agencies organization has undertaken an investigation of source water quality upstream of the Delta. Results of this study are expected in 1994.

Source Protection

Urban and agricultural pollutants, mineralization, eutrophication, toxic chemicals, precursors, and pathogens all affect water quality and present complex challenges for water managers. Compared to other parts of the country, California has some distinct advantages in dealing with water quality problems. California was settled only recently compared to other states, and most of our growth has occurred since World War II. Generally, we are not faced with the problem of antiquated sewer systems and other more difficult environmental problems experienced by states with facilities installed long before World War II. Fortunately, environmental awareness and regulatory control came about in California before its water resources were severely damaged. However, certain problems exist, such as siltation and toxic element residues in the tributaries of the Sacramento-San Joaquin Delta (mostly from hydraulic mining operations of the late 1800s).

The quality of surface waters in various parts of California is affected by localized conditions. The SWRCB and its Regional Water Quality Control Boards enforce the federal Clean Water Act in California on behalf of the U.S. EPA. These agencies document

Principles of Water Utility Management as Set Forth by the Source Water Quality Committee of the California-Nevada Section, American Water Works Association

As a result of the April 1993 outbreak of Cryptosporidiosis in Milwaukee, President Foster Burba of the American Water Works Association called on its membership to test water supplies for the presence of *Cryptosporidium*, and said, "Not only are we issuing this national call to action on testing, we're strongly encouraging water utilities to develop stricter watershed management and treatment practices."

The Source Water Quality Committee of the California-Nevada Section of the AWWA adopted the following statement on April 14, 1993:

The Source Water Quality Committee of the California-Nevada Section of the American Water Works Association supports the fundamental objectives of providing drinking water from the best quality sources reasonably attainable, and of managing such sources to protect and enhance water quality.

With increasingly stringent drinking water regulations, it is important that water utilities obtain and maintain supply sources of the best available quality. Water utility managers should implement the following principles:

1. Where alternative sources of supply are available, drinking water should be taken from the highest quality source reasonably attainable.
2. Where there are competing uses for water sources, public drinking water should be the highest priority use.
3. The quality of existing and potential sources of drinking water, including both ground water and surface water, should be actively and aggressively protected and enhanced. Source water quality protection programs should:
    - Determine and monitor the existing quality, and future changes of quality, of all water sources.
    - Determine factors influencing, and potentially affecting, source water quality; including both point and nonpoint contaminant sources, and continuous, seasonal, and ephemeral contamination.
    - Implement an active program of monitoring and managing activities in source water bodies, aquifers, and watersheds to minimize contamination and drinking water degradation.
4. Decisions regarding alternative resources uses and development should give full consideration to impacts on water quality—including public health, economic, aesthetic, and environmental impacts.
5. Encourage water reuse and use of lower quality water for appropriate purposes.

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many water quality problems and are developing more restrictive water quality criteria and preparing regulatory actions to make further improvements. The control of disinfection byproduct precursor compounds in source waters is a problem that has not been resolved, but is one of the issues being considered by the Bay/Delta Oversight Council.

Important among California's current water quality concerns is the relatively recent discovery that certain widely used chemical agents, particularly chlorinated solvents, can infiltrate and pollute ground water. This revelation motivated a number of investigative and regulatory actions. Major urban centers in California have had to abandon wells or provide expensive treatment to remove chemicals from municipal ground water supplies. The consequences of this problem are reduced water supply and water management options for local water agencies.

Regulatory actions, such as requiring leakage protection for underground tanks, eliminating unlined chemical pits, and regulating disposal practices, are making important contributions to prevention of further ground water degradation.

A basic tenet of good sanitary engineering practice is to obtain the best quality drinking water source available and to protect and maintain its quality. By following this practice, not only are water supplies treatable to meet drinking water standards, but the variations in source water quality are also minimized to improve treatment reliability.

Some municipal water supply agencies, with the backing of the Department of Health Services, are able to control and protect the local watershed sources of their drinking water supplies. This control prevents activities that might reduce the reliability of their water treatment processes to produce safe drinking water.

Similar protection for Delta and Colorado River water supplies is out of the question. Watersheds tributary to the Delta and Colorado River drain thousands of square miles of land surface, and it is impossible to prevent activities that affect the quality of the water. Inability to protect the watershed fully means that water treatment processes used may not reliably remove all chemical agents present in the water.

In its 1993 report, *Drinking Water into the 21st Century*, the California Department of Health Services wrote, "Contamination of ground water has received the most attention due to news media coverage of toxic waste sites and spills. Yet, the exposure and risks from ground water contaminants are significantly lower than the exposure and risks from surface water." The report also contains the quotation, "The Delta, through which the State Water Project flows, provides the most significant threat to the quality of drinking water supplies." This report recommended,

> *To the extent feasible, measures should be taken to prevent degradation of the domestic water transported through the Delta by minimizing the introduction of disinfection byproduct precursors from agricultural operations and by controlling seawater intrusion into the Delta. The domestic water supply should be further protected from agricultural drainage and other sources of potential degradation during transport through the State Water Project and other aqueducts.*

In 1990, at the request of the Department of Health Services, the State Water Contractors completed a sanitary survey of the SWP. The survey identified potential sources of quality degradation in the watersheds tributary to the SWP, with particular emphasis on the Delta. The resulting report contained a number of recommendations for correcting identified problems. Since publication of the report, an action plan has been in the process of development, and is expected to be implemented in 1994.

Critical Components of State Water Supply

Water quality considerations in the Sacramento–San Joaquin Delta and its tributary streams (principally the Sacramento and San Joaquin rivers), in the Colorado River, and in ground water will significantly influence management of these critically important source water supplies. The following sections summarize water quality considerations in California's water supply.

Sacramento–San Joaquin Delta Water Quality

Delta waters provide a rich habitat for fish and wildlife and are the major source of supply for uses throughout the State.

Delta Ecosystem and Water Quality. The Delta provides habitat for many species of fish. Unfortunately, some are in serious decline. Striped bass, winter–run salmon, and Delta smelt are fish whose evident declines have generated much attention. Pollution has been suggested as a cause of some of the problems. Some studies indicate a link between the presence of certain chemicals from waste discharges and the reduced health of fish. Although less well known, other fish species are also in decline in the Delta and are probably affected by some of the same factors as striped bass and salmon.

The effects of lethal doses of poison on fish are relatively simple to evaluate. Much more difficult is the problem of assessing chronic low-level effects of toxicants on the health and productivity of fishery resources. Because fish are residents of the water, they may be constantly exposed to low-level toxicants. Scientists are learning that, in some cases, very low concentrations of some chemicals can have health effects on fish. New methods of analyzing chemicals at very low concentrations are being developed, along with new methods for testing the effects of low toxicant levels on fish. Unfortunately, inadequate evidence exists to aid basic fishery management decisions.

Drinking Water Supply. Drinking water for about 20 million Californians flows through the Sacramento–San Joaquin Delta. The water is influenced by so many factors that it is not always clear which particular influences may be causing problems. However, some facts are known. It has been clearly established that sources of naturally occurring organic materials in the Delta double the capacity of Delta waters to form unwanted byproducts in drinking water.

Drinking water produced by treating Delta waters usually meets all State and federal drinking water criteria. There have, however, been occasions when the existing trihalomethane regulations have not been met. In addition, compliance with the Surface Water Treatment Rule, required beginning June 1993, has caused some major Delta water users to change their disinfection practices, which produce even higher levels of trihalomethanes in some cases.

Measurements by the Department of Water Resources and municipal agencies that treat and serve Delta water to their customers have demonstrated that concentrations of pesticides, toxic elements, and other chemicals in Delta waters are quite low in relation to drinking water standards. However, pesticide degradation product studies in these waters are in early phases and the information is preliminary.

Compared to other sources of drinking water, the Delta is at a disadvantage with respect to the presence of disinfection byproduct precursors and the ability of urban water suppliers to provide consistently acceptable drinking water. Bromide is present in the Delta, chiefly as a result of the intrusion of sea water mixing with the fresh water in the Delta. Also, the peat soils of the Delta are high in organic content and contribute dissolved organic matter to Delta waters. Together, bromide and naturally occurring organic compounds present in the Delta cause problems for treatment facilities and their ability to meet current drinking water standards for trihalomethanes.

Figure 5-1 depicts the potential of Delta waters to form trihalomethanes, a form of disinfection byproducts. (Figure 5–1 was derived from data in *The Delta as a Source of Drinking Water, Monitoring Results, 1983 to 1987*, August 1989, Department of Water Resources.) The size of each pie is proportional to the capacity to form trihalomethanes at that location. The shaded portions of each pie depict the influence of bromide on the total. The Sacramento River is shown as having a considerably lower capacity to form trihalomethanes, as compared to locations in the southern and western Delta. Table 5-4 shows averages of selected constituents in the Delta and Colorado River.

The western Delta has higher organic precursor concentrations, along with much greater bromide influence. The interior Delta locations depicted are intermediate in organic precursor concentrations and bromides. Studies indicate that the bromides present in Delta waters come mainly from sea water intrusion; the naturally occurring organic compounds in Delta waters come from numerous sources, including significant influence of Delta island drainage from soils rich in organic content.

Municipal agencies supplying drinking water taken from the Delta are concerned that existing regulations for trihalomethanes, coupled with disinfection requirements of the new Surface Water Treatment Rule may make Delta water difficult and expensive to treat. The expected new, more stringent, drinking water regulations for trihalomethanes and other disinfection byproducts may particularly increase the difficulty and expense of treating Delta water. Even if drinking water from the Delta meets the criteria, the desirable level of a carcinogen in drinking water is zero (the maximum contaminant level goal as defined in the 1986 amendments to the Safe Drinking Water Act). At best, drinking water from the Delta is not likely to be as low in disinfection byproducts as water from other sources.

Potentially, it would be possible to improve the quality of Delta drinking water by taking actions to reduce bromides and naturally occurring organic compounds in the water supply. Several possibilities are currently being examined through the Municipal Water Quality Investigations Program, a multi–agency scientific investigation into the factors contributing to disinfection byproduct formation in Delta waters. Possible means of improving this aspect of Delta water quality are also being studied. The results will be used in the Delta planning process.

Salt gets into Delta water from its watersheds and its link with the San Francisco Bay and the Pacific Ocean. Tidal action from the Bay brings salts into the Delta during periods when fresh water outflows are low. With the exception of bromide, salts in drinking water are generally of lesser concern. However, elevated salt concentrations can make water unpalatable and the health of persons on low–salt diets can be adversely affected. During the 1976–77 drought in California, salt content in water from the Delta was such that physicians in Contra Costa County recommended bottled water for some patients. Similar levels occurred during the recent drought.

Delta influences add about 150 mg/L (parts per million) of dissolved solids (salts) to waters exported in the SWP. Using generalized cost figures taken from the *Costs of Poor Quality Water* section of this chapter, the cost to consumers of this salt is on the order of $120 per acre-foot, which is roughly the amount of water an average family uses in a year. These costs arise primarily from the need to use more soaps and detergents, and to more frequently replace plumbing fixtures and water-using appliances.

Figure 5-1. Disinfection Byproduct Precursors in the Delta: July 1983 to June 1992

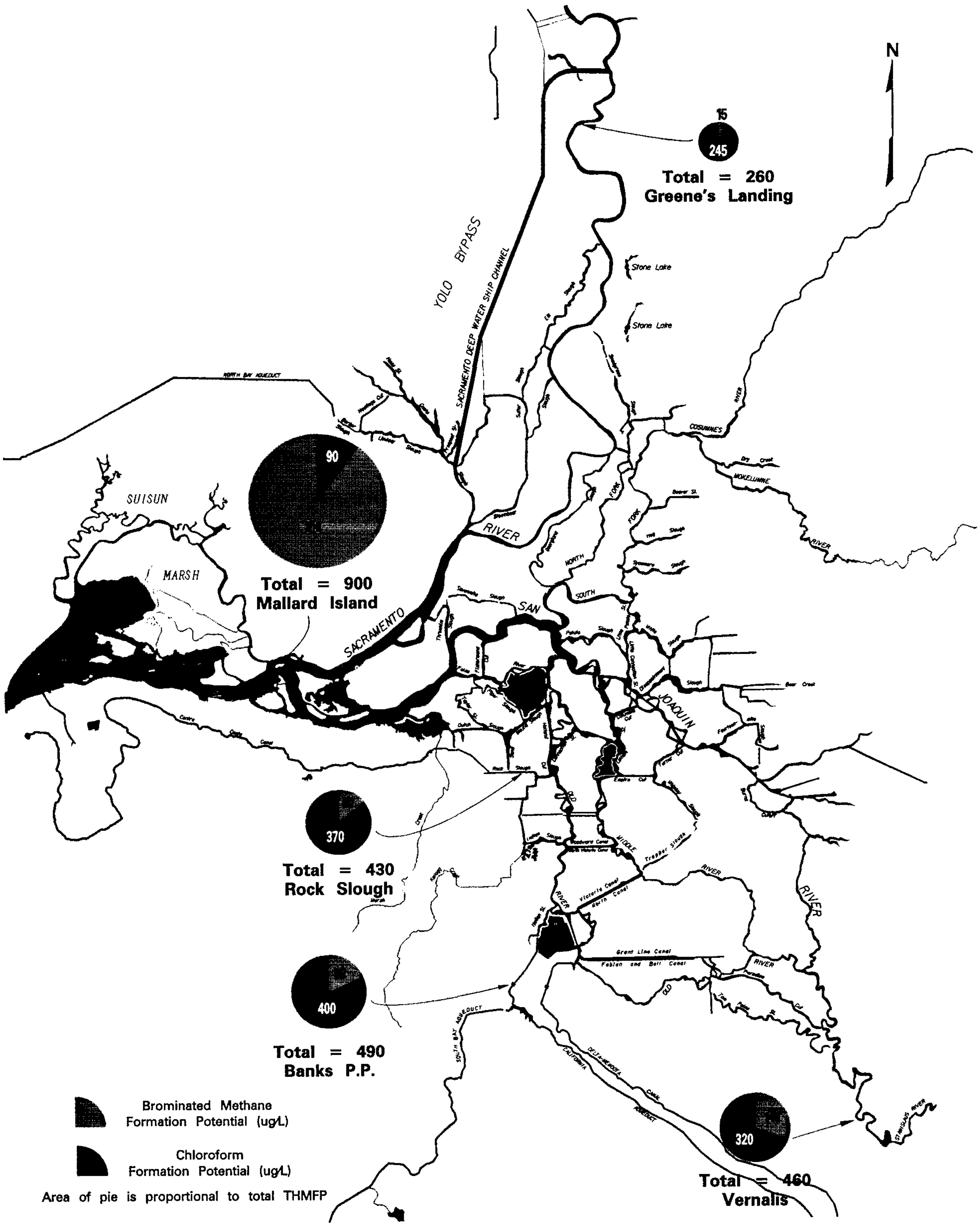

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Table 5-4. Average Water Quality of Selected Sources, 1986 to 1992*

(milligrams/liter or ppm)

	TDS	*Fluoride*	*Bromide*	*TOC*	*DOC*	*TFPC (ug/L)*	*Arsenic*	*Barium*	*Cadmium*	*Chromium*	*Copper*	*Lead*	*Lithium*	*Mercury*	*Selenium*	*Zinc*
Sacramento River at Greene's Landing	108	—	0.03	2.34	2.39	28	<0.01	—	<0.01	<0.01	<0.01	<0.01	—	—	<0.001	<0.01
San Joaquin River near Vernalis	519	—	0.42	3.52	3.86	44	—	<1	—	<0.005	<0.005	—	<0.005	—	0.002	0.014
Harvey O. Banks Pumping Plant	310	0.1	0.35	3.33	4.00	51	0.002	<0.05	<0.005	<0.005	<0.007	<0.005	—	<0.001	<0.001	<0.017
Colorado River Aqueduct**	580	0.29	0.06	2.97	—	16	0.002	0.153	<0.001	<0.002	<0.01	<0.005	0.035	<0.0002	0.002	<0.02
Colorado River at Imperial Dam**	679	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Federal Criteria for Drinking Water																
Primary MCLs	—	4	—	—	—	—	0.05	2	0.005	0.1	TT(1.3)†	TT(0.015)†	—	0.002	0.05	—
Secondary MCLs	500	2	—	—	—	—	—	—	—	—	1	—	—	—	—	5

*Not all parameters were sampled for the full period.
** Arithmetic average, not flow weighted
†For lead and copper, treatment technique is used in lieu of numeric maximum contaminant levels.
TDS: total dissolved solids
TOC: total organic carbon
TFPC: trihalomethane formation potential carbon
Primary MCL: drinking water standard for protection of health
Secondary MCL: drinking water standard for protection of aesthetic qualities, such as taste
DOC: dissolved organic carbon
Note: For most of the 1986 to 1992 period, the Sacramento-San Joaquin Delta and its tributaries experienced drier hydrologic conditions than existed in the Colorado River System. In a more normal hydrology, mineral concentrations in Delta waters could be expected to be lower than depicted here.

These costs could be avoided if the effects of ocean salinity intrusion and local Delta drainage could be eliminated.

Some of the industries in the Delta area, such as paper production facilities, require water of limited salt content. Satisfying this requirement can present a formidable challenge in dry years due to sea water intrusion. In the past, this problem has been dealt with by relying on alternate water supplies and treatment.

Delta Agriculture and Wetlands. While the quality of Delta water available to agriculture is generally satisfactory, certain conditions create problems with salt content. Sufficiently high concentrations of salt can stunt or kill plants. When salt content is high, more applied water is required for irrigation to flush the salts through the root zone. The San Joaquin River is a significant source of salt due to agricultural drainage flows into the river upstream of the Delta. Much of this salt load originated in the irrigation water exported from the Delta. At times, salts from this source adversely affect agriculture in the southern Delta. Recent mitigation measures, such as installing temporary rock barriers in certain Delta channels, improved the overall quality of water in the southern Delta.

Some Delta lands are used as wetland habitat for waterfowl and other wildlife. This type of land use is likely to expand in the Delta. The quality of water available to support wetland habitat is generally adequate.

Water Quality Monitoring in the Delta. DWR and other agencies extensively monitor water quality in the Delta. The monitoring evaluates Delta waters as a source of drinking water for humans, as a source of agricultural and industrial water supply, and as habitat for fish and wildlife. Water quality parameters monitored include minerals, nutrients, pesticides, and other constituents such as organic carbon and trihalomethane-forming capacity. Extensive biological monitoring is also performed.

In a number of locations, such constituents as minerals and photosynthetic activity are monitored continuously by permanently installed instruments that provide information through remote sensing and data transmission. DWR is currently compiling an inventory of all known water quality monitoring activity in the Delta by public entities. The compilation indicates a great deal of interest in the quality of Delta waters. Millions of dollars are invested each year in the pursuit of assessing Delta water quality.

Sacramento River Region. The Sacramento River, on average, provides about two-thirds of the water which flows into the Delta. A number of other watersheds are tributary to the Delta, but of these, only the San Joaquin River is significant in terms of quantity of flow. The quality of the water in the Sacramento River is generally good, and mineral concentrations are low. For the period 1983 to June 1992, DWR data indicate that dissolved solids concentrations ranged from about 50 to 150 milligrams per liter in the Sacramento River at Greene's Landing, located eight miles south of the town of Hood. For comparison, the maximum contaminant level for dissolved solids in drinking water is 500 milligrams per liter. (This "Secondary MCL" was established to protect the aesthetic appeal of drinking water, as concentrations above the limit result in noticeably salty tasting water.)

SWRCB has classified 80 miles of the Sacramento River from Shasta Dam to below the town of Red Bluff as impaired with respect to water quality. Twelve miles below the dam is the confluence of Spring Creek with the Sacramento River. At this point, significant concentrations of the toxic metals copper, zinc, and cadmium enter the river as a result of acid mine discharges from mines on Iron Mountain. Several fish kills have occurred in the river below the mouth of Spring Creek following heavy runoff from the Iron Mountain area. The Central Valley Regional Water Quality Control Board has recently been conducting toxicity bioassay tests on minnows, zooplankton, and algae using Sacramento River water collected in the reach from Keswick Dam to Hamilton City. The results of these tests should help determine the degree of water quality impairment of the river and should show what length of river is affected. Large releases of fresh water are made annually from Lake Shasta in efforts to dilute the pollution to nontoxic levels. South of Red Bluff, water quality improves and only periodic toxicity is observed.

Colusa Basin Drain enters the Sacramento River at the town of Knight's Landing. Bioassay testing has indicated significant toxicity to aquatic life associated with agricultural discharge from this drain. (Bioassays are conducted by exposing test organisms, such as minnows, to varying concentrations of the water being tested, mixed with water containing no toxicants. The toxicity of the water can be judged by observing the effects on the test organisms.)

In the early 1980s, agricultural pesticides used on Sacramento Valley rice fields were determined to be the cause of fish kills in some agricultural drains and of complaints from Sacramento residents about the taste of the water. A multi-agency team that included public agencies and agricultural and rice industry participants was established to confirm the cause of the problem and find a solution. The team resolved the problem by designing a monitoring and control program which has been very successful in reducing rice herbicide concentrations in the Sacramento River since 1986. Reductions of molinate and other agricultural chemical residue can also be attributed to use of improved chemicals requiring lower usage, use of disease-resistant and weed-resistant rice strains, better water management, and integrated pest management practices. Figure 5-2 depicts the dramatic reduction in discharges of the rice herbicide molinate from 1982 through 1992.

While reduction of agricultural drainage is generally desirable for protection of water quality, it is also true that long-term reductions in drainage can have the undesirable effect of causing salt buildup in agricultural soils. Numerous ancient civilizations declined as a result of soil infertility associated with salt buildup. There-

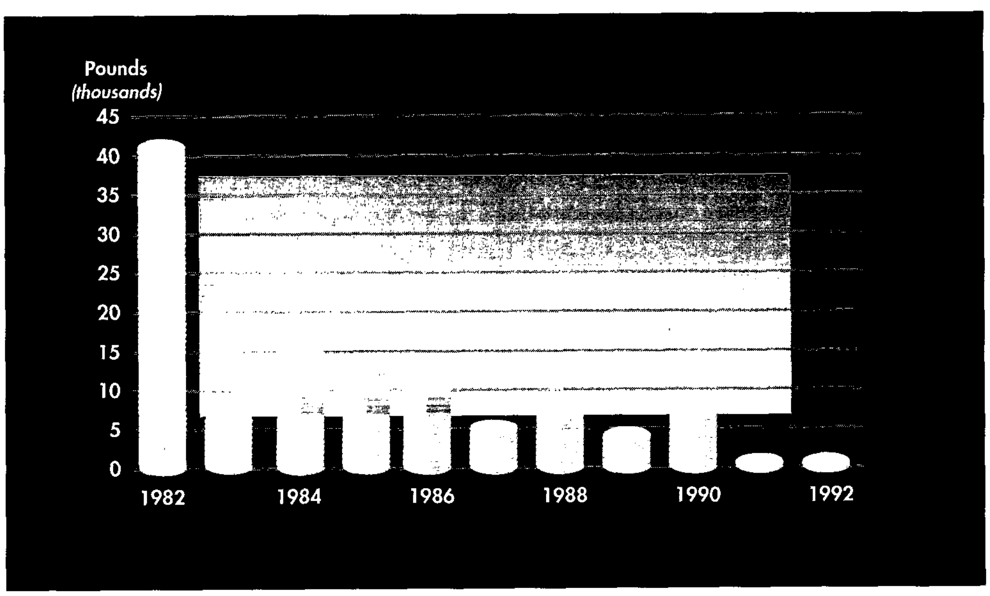

Figure 5-2. Mass Discharge of the Rice Herbicide Molinate to the Sacramento-San Joaquin Delta

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fore, it is necessary to balance the need to protect water quality with the need to maintain the fertility of our agricultural lands.

Monitoring the lower Sacramento River has shown that levels of pesticides, disinfection byproduct precursors, toxic metals, and other constituents of concern are generally not detectable or have been present only in small concentrations as the river flows into the Delta. The organic content of the Sacramento River is generally low, and bromide concentrations are quite low. During the fall when rice fields are drained into the Sacramento River upstream of Sacramento, the concentration of organic disinfection byproduct precursors in the river measurably increases.

The Sacramento regional waste water treatment plant discharges into the Sacramento River near Freeport. The plant provides a high level of treatment and is in compliance with its discharge requirements a high proportion of the time. The plant does not, however, remove minerals from the water. This causes the total dissolved solids concentration of the river to increase a few percent in the low flow periods of summer and early autumn.

San Joaquin River Tributary. On average, about one-sixth of the total fresh water inflow to the Delta comes in from the San Joaquin River. (Other east side streams such as the Cosumnes and Mokelumne contribute no more than a few percent of Delta inflow, and are of generally excellent quality.) Unlike the Sacramento River, the mineral quality of the San Joaquin River is not very good during low flow periods. During high flow conditions, the mineral quality of the river can be quite good. The elevated salinity levels in the river are, in part, a result of significant amounts of valley agricultural drainage returning to the Delta through the San Joaquin River. At certain times, most of the river flow can be composed of agricultural drainage. In recent years, releases from reservoirs such as New Melones have helped meet water quality standards in the lower San Joaquin River. Data from 1982 through May 1992 indicate levels of dissolved solids in the San Joaquin River near Vernalis have ranged from about 110 to 900 milligrams per liter; the numbers reflect high and low flow conditions, respectively.

A popular perception is that the San Joaquin River is very heavily polluted by pesticides and other toxic agricultural chemicals. In fact, data have demonstrated that pesticide concentrations, when present, have been at low parts per billion concentrations, well within drinking water standards. While measured pesticide concentrations have been low by drinking water standards, recent measurements by the U.S. Geological Survey and the Central Valley Regional Water Quality Control board indicate the presence of certain insecticides in the tributaries to the Delta. Evidence indicates that, during wet periods, these levels can be present in pulses high enough to produce indications of widespread toxicity in the Bay-Delta estuary for short periods of time.

The San Joaquin River watershed has a special problem with selenium. In 1983, it was discovered that selenium in valley agricultural drainage was responsible for deformities and lack of reproductive success in bird populations. Subsequent regulatory action resulted in the closure of drainage facilities that contributed to the problem and development of management strategies for controlling selenium. Selenium concentrations currently found in the San Joaquin River where it enters the Delta are typically not higher than 1 microgram per liter (part per billion). For comparison, California drinking water Maximum Contaminant Level for selenium is 10 micrograms per liter and the federal MCL is 50 micrograms per liter.

Selenium from the San Joaquin River watershed has an effect on the aquatic environment even though it is not considered a threat to drinking water quality. In small concentrations, selenium is an essential nutrient, but studies have indicated that concentrations as low as a few micrograms per liter may be harmful to sensitive species. Work is continuing to find the means to better manage and control selenium in the San Joaquin Valley.

Colorado River Water Quality

The Colorado River is a major source of water supply to Southern California. The river is subject to various water quality influences because its watershed covers thousands of square miles and runs through parts of several states. The watershed is mostly rural. Therefore, municipal and industrial discharges are not as significant a source of quality degradation as is the case for the waters of the Delta. Upstream of the point where the Metropolitan Water District of Southern California draws water from the river, the primary water use is agricultural. Salt and turbidity from natural sources and agricultural operations are the primary forms of water quality degradation.

Mineral concentrations in Colorado River water are typically higher than those found in the water taken from the Delta through the SWP. During the period 1986 to 1992, dissolved solids in the Colorado River Aqueduct averaged 580 mg/L (parts per million). During this period, dissolved solids concentrations in the California Aqueduct of the SWP averaged 310 mg/L.

As practicable, MWDSC blends Colorado River water with water from the SWP or other sources to reduce salt concentrations in the water delivered to consumers served by the district's system. This improvement resulted in MWDSC discontinuing use of the sodium-exchange softening process for Colorado River water in 1975.

Unlike the watersheds of the Delta, the soils of the Colorado River watershed are primarily low in organic content. Consequently, disinfection byproduct precursor concentrations are lower. Colorado River water typically has 2.5 to 3.0 milligrams per liter of total organic carbon and 0.06 milligrams per liter of bromide. As a result, it normally has only about half the capacity to produce trihalomethanes as does water in the Delta. Disinfection of Colorado River water with ozone has not produced measurable levels of bromate.

Most of the water released from Parker Dam is used for irrigation in the Imperial and Coachella valleys and in northeastern Baja California. The agricultural drainage from the two valleys in California as well as much of the drainage from the irrigated area in Baja California flows into Salton Sea.

The agricultural drainage waters have high salinities which, when combined with evaporation from the sea itself, lead to a continuing increase of the Salton Sea salinity. The current concentration of dissolved solids (salts) in the sea is about 45,000

Agricultural drainage in the Imperial Valley contains high concentrations of naturally occurring salts and minerals.

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mg/L (parts per million), whereas the concentration of dissolved solids in ocean water is about 35,000 mg/L. Since the sport fish in the sea were imported from the ocean, the high salt concentration places considerable physical stress upon the fish.

In 1973, the seven states within the Colorado River basin formed the Colorado River Basin Salinity Control Forum to develop numeric criteria for controlling salinity, and to develop plans to implement controls. This group was formed in order to comply with the 1972 Federal Water Pollution Control Act, requiring water quality standards for salinity in rivers. Salinity standards for the basin were promulgated in 1975 and were subsequently approved by the U.S. Environmental Protection Agency. The Forum established a permanent work group to perform studies and triennial reviews of progress and to make recommendations for continuing improvements in salinity control.

The federal Colorado River Basin Salinity Control Act of 1974 authorized construction of facilities to control salinity of the waters of the Colorado River which are used in the United States and Mexico. Currently, salinity control activities are removing 230,000 tons of salt per year from the river system. However, inadequate funding is causing problems in maintaining the implementation schedule. To maintain the salinity standards, it is calculated that, by the year 2010, about 1,500,000 tons of salt will have to be removed each year.

Ground Water Quality

About 40 percent of California's annual total urban and agricultural applied water use is provided by ground water extraction. Unfortunately, being out of sight has meant that California's ground water has often been out of mind. As a result, laws to protect and manage ground water have been slow in developing, as has the awareness of the potential for pollution of some of California's ground water basins. Degradation of these water resources is the most significant threat to our ability to integrate and manage our ground water resources with surface waters.

In the mid-1970s, an investigation of ground water conditions in the vicinity of a Stockton area manufacturing plant resulted in the discovery of significant pesticide pollution. Prior to this investigation, general thought was that the natural process of water percolating through the soil removed pesticides within the first few inches or feet of soil. Statewide surveys were conducted leading to knowledge that polar, low-molecular-weight, volatile compounds such as solvents rapidly penetrate the soil and enter the ground water. Once there, they may remain for hundreds of years. Now, water managers know that cleaning up ground water pollution is quite difficult and costly.

Ground water has often been polluted in agricultural areas where soils have been fumigated to eradicate soil organisms and in industrial areas where solvents have been improperly handled. In the case of industrial pollution, the use of solvents was accompanied by indiscriminate disposal practices, such as dumping waste material on the ground or in unlined ponds.

In the San Gabriel Valley of the greater Los Angeles area, solvent pollution is so widespread in the ground water that it is generally not possible to identify individual sources and assign cleanup responsibility. In other areas of California, such as the Silicon Valley in Santa Clara County, cleanup responsibility has sometimes been assigned to specific industries. There, electronic industries which released solvents into the ground (often because of leaky underground storage tanks), are proceeding successfully with cleanup efforts which are costing millions of dollars.

Leaking underground tanks have been found to be a particular problem. Gasoline storage tanks and most other types of underground chemical storage tanks were, until recent years, constructed in a way that caused the tanks to fail as they corroded. As a result, ground water contamination from these sources is widespread. SWRCB now manages a program to control contamination from underground tanks.

Ground water contamination by synthetic organic pollutants may be more serious than surface water pollution because of the difficulty and expense of cleanup. This type of pollution is widespread in California and presents a serious challenge. However, the water can be treated to remove solvents, and the water can then be used.

An even more complex problem than presented by solvents is the problem of nitrates. Nitrates are nitrogen-containing compounds required to support plant life. They may enter the soil as a result of fertilizer applications, animal waste, septic tanks, industrial disposal, waste water treatment plant sludge application, or other sources. Certain organisms even have the capacity to take nitrogen from the air and convert it into nitrates. In California, the most important source of nitrates in soils is from agricultural practices, primarily farming operations and animal husbandry.

Nitrates have the capability to move through the soil into ground water and, once there, may seriously degrade its usability. There is a limit to the concentration of nitrates people can tolerate; infants, in particular, are susceptible to nitrate poisoning (methemoglobinemia). Nitrates can also limit the use of ground water for other purposes such as stock watering. In too high concentrations, nitrates become toxic to plants. The biggest problem with nitrates is that treatment to remove them is so expensive that it is impractical in most situations. Communities having water supplies high in nitrates often turn to bottled water for cooking and drinking.

Nitrates are widespread in California's ground water. For instance, the Petaluma area of Sonoma County was historically an important poultry production area. Poultry waste was generally piled up and left to decompose on the site of the poultry operation. Poultry waste is a potent source of urea and organic nitrogen, which can convert to nitrates and then migrate into the ground. Even after poultry operations were discontinued, plumes (feather-shaped bands) of nitrates remained in the ground. When it rains, water percolates down through these plumes and dissolves some of the nitrates, carrying it into the water-bearing stratum below. A 1981 study demonstrated nitrates in the Petaluma area's ground water ranging to over 300 milligrams per liter, significantly exceeding the California's Maximum Contaminant Level of 45 mg/L for drinking water.

Efforts must focus on better controlling nitrate pollution at the outset since nitrate removal from ground water is not usually economically feasible. Increasing awareness of this problem at the federal and State levels has improved regulatory attention to nitrate pollution. In some parts of the country, nitrate-laden water is pumped from underground and applied as fertilizer, thus reducing the need for added nitrogen fertilizer.

Remediation and Protection of Ground Water Quality

Protection and maintenance of California's ground water resources will require the participation of all Californians. Significant ground water pollution has occurred as a result of individual actions, including those of homeowners who dispose of solvents by spreading them on their property. Individual citizens and industrial workers can help greatly by disposing of toxic and hazardous materials in a safe, environmentally acceptable manner.

Quality Considerations for Water Reclamation and Reuse

As discussed in Chapter 3, water reclamation (recycling) and reuse make more efficient use of existing supplies, but the extent of reuse depends on the quality of the source supply, local economic conditions, the amounts and types of reuse already instituted, and the intended applications of the recycled water.

Fresh water can be saved for environmental enhancement or other uses to the extent reclaimed waste water can be used in its place. However, there are also concerns about the use of reclaimed water. In some cases, human health risks may be increased by pathogenic organisms or chemical residues which could be present in reclaimed water.

The Office of Drinking Water within the California Department of Health Services is responsible for regulating use of reclaimed waste water. Regulations stipulate treatment levels for use of reclaimed water for various purposes such as irrigation, recreation, and ground water recharge. The objective of these regulations is to allow the maximum use of reclaimed water while protecting public health. More specific regulations are expected concerning the use of reclaimed water for recharge of ground water supplies.

The quality required of reclaimed water depends on its use. Possible uses include landscape irrigation, growing food for animals, industrial uses such as wash water, flushing toilets, ground water recharge, and other uses which do not involve direct human consumption. The concentration of salts in the waste water is a determining factor of its availability for most uses. Water increases in salt concentration as a result of being used. Also, some waste water pipelines have picked up salt from saline ground water, such as near San Francisco Bay. In cases where fresh water supplies already contain elevated salt concentrations, the waste water resulting from use of this water may be quite limited in its usefulness.

Limited quantities of reclaimed water are being used in California to recharge ground water for subsequent municipal water supply, and other potential projects are being studied. Water quality requirements are quite stringent for projects involving human consumption of reclaimed water. The primary concerns are pathogenic organisms and harmful chemical residues. Treatment processes used for recharging potable water supplies must not only successfully remove harmful constituents, but also be highly reliable.

The Department of Health Services evaluates all proposals for potable use of reclaimed waste water on a case-by-case basis. As treatment technology advances, it may become possible for waste water to be adequately and reliably treated for direct municipal reuse. Representatives of the Departments of Health Services and DWR currently co-chair a technical committee examining this issue.

Costs of Poor Quality Water

Water of reduced quality is generally associated with a cost to the user. The cost depends on the quality of the available water, its intended use, and the treatment processes required to meet standards specified for the intended use. Drinking water standards and those for municipal, industrial, and agricultural water use specify the quality requirements that must be attained before the water can be used beneficially. New standards, such as the one requiring drinking water filtration, and ones which have lowered the acceptable limit of lead and copper, often result in increased costs of treatment to meet the new standards. In some cases, the cost can be very high. The City and County of San Francisco, for example, may have to incur high costs if they are required to construct filtration facilities as a result of the Federal Surface Water Treatment Rule which generally requires filtration and rigorous disinfection of surface drinking water supplies. In California, the SWTR will be administered by the State Department of Health Services.

In general, the better the quality of the source for drinking water, the less treatment it requires and, consequently, the less it costs to produce. Many water quality parameters affect treatment costs, including microbiological quality, turbidity, color, alkalinity, hardness, and bromide and organic carbon content. For example, MWD treats roughly 6,000 af of water per day at five major treatment plants. Recently, the district made improvements, costing about $5 million, to its treatment processes. To meet the expected more stringent trihalomethane rule, MWD is studying the need for further improvements with a capital cost range of $300 million to $2 billion.

The mineral quality of municipal supplies has a variety of impacts in addition to affecting drinking water quality. Hard water (high in calcium and magnesium salts) can cause corrosion, staining, and scale buildup and require excessive use of cleansers. Soft water may attack the metal in plumbing, increasing lead and copper concentrations at the tap.

Many studies have cited the impacts of water quality on the value of water to urban consumers, and all have cited the difficulty of expressing quality impacts in a simple way. A 1989 review of consumer impacts of the mineral content of Delta water proposed a generalized cost of $0.68 per acre–foot per milligram per liter of incremental total dissolved solids. The current generalized value would be about $0.80 per acre–foot per milligram per liter (adjusted using the Consumer Price Index), or about $0.30 per pound of dissolved mineral matter in the water. The impact of this added cost can be quite significant.

Studies have also shown that lower water quality in urban supplies increases consumer use of bottled water and home treatment devices. Surveys of California communities indicate that about half of all California residences use some bottled or home–treated water. The collective cost of these choices by California's residents is over a billion dollars annually. Some of these expenditures would, of course, be made regardless of local water quality.

A less obvious impact of water mineralization is the limiting of water recycling opportunities, especially in areas where reclaimed water percolates back into ground water basins. With each reuse, the reclaimed water is more heavily mineralized and thus eventually becomes unusable. This phenomenon is more pronounced where common salt is added to regenerate water softeners, and the waste brine also enters ground water. Under these conditions, the mineral pickup per cycle of use can be increased several fold. Several areas of California have banned the use of water softeners because of these circumstances.

There is great variation in the water quality requirements for industry. In many industries, tap water is not of adequate quality for certain processes and must receive additional treatment, such as softening. The costs of having unacceptable water quality for industry generally depend on the cost of the additional treatment that may be necessary.

Salty irrigation water presents several costly problems for farmers. In many agricultural areas, it is common to recirculate irrigation water a number of times to increase irrigation efficiency. Salty water can be recycled fewer times than water that is initially low in salt. Also, more salty water must be used for irrigation than is required when using supplies low in salt. The requirement to use more water results in significant additional cost for pumping and handling the water and, perhaps, additional cost to purchase the water.

Generally, the most salt-tolerant crops are not the ones having highest value. Therefore, given a salty water supply, a farmer may be required to grow less valuable crops than is possible when low-salt irrigation water is available. Finally, crop yields fall as salt in the irrigation water increases beyond the optimal ranges specific to individual crops.

Numerous aspects of water quality can affect fish and wildlife habitat and result in monetary or environmental costs. An example is selenium in agricultural drainage from the San Joaquin Valley which was used to supply wetland habitat in the valley. In this case, elevated selenium concentrations caused severe reproductive damage to fish and wildlife species, particularly to birds using the wetlands.

There are many water quality problems which can result in cost, either direct or environmental. In turn, these impacts reduce flexibility in water supply planning and water management. The real challenge is to avoid these costs by protecting water sources from quality degradation in the first place. California's record has been a good one, for an industrialized state. Most of our waters remain fit for fish and wildlife, and for multiple uses by people. However, the rapidly growing population, along with continued industrialization, will continue to greatly challenge our ability to maintain and improve water quality. If we are to meet this challenge successfully, it will require the best efforts of government, the water industry, and, most of all, concerned citizens. To fail to meet this challenge would be to lose the use of precious water resources that cannot be spared.

Recommendations

1. Increasingly stringent and costly drinking water quality standards for public health protection will affect the continued availability and cost of water supplies. More effort must be made by State and federal agencies to balance the cost with public health and other benefits of such standards.

2. Research into relationships and effects of water quality degradation on fish and wildlife should continue. In particular, more information is needed on acute and chronic effects of low-level toxicants on the health and reproductive capacity of aquatic organisms. (Research should be a cooperative effort by State and federal agencies.)

3. Urban water supplies diverted from the South Delta face the threat of increasing water quality degradation from both salinity intrusion and organic substances originating in Delta island drainage. Factors responsible for quality degradation from Delta island drainage should be investigated by State agencies, and potential means of mitigating problems identified.

4. Reuse of adequately treated waste water can, in some areas, provide alternative sources of supply as well as benefit fish and wildlife resources, particularly in arid portions of the State. Efforts by State agencies should be continued to define the conditions and degree of treatment needed to allow use of treated waste water for beneficial uses and discharge of effluents to water courses so that these benefits can be realized.

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Introduction

Water Use

This part of Bulletin 160-93 covers urban, agricultural, environmental, and recreational water use. Certain key concepts, defined below, are important to understand before reading the following chapters because they are employed in analyzing water use and presenting results of planning studies.

Applied Water Demand: The amount of water from any source needed to meet the demand of the user. It is the quantity of water delivered to any of the following locations:

- the intake to a city water system or factory
- the farm headgate
- a marsh or wetland, either directly or by incidental drainage flows; this is water for wildlife areas

  For existing instream use, applied water demand is the portion of the stream flow dedicated to: instream use (or reserved under the federal or State Wild and Scenic Rivers acts); repelling salinity; or maintaining flows in the San Francisco Bay/Delta under State Water Resources Control Board's standards.

Net Water Demand: The amount of water needed in a water service area to meet all requirements. It is the sum of evapotranspiration of applied water, ETAW, in an area; the irrecoverable losses from the distribution system; and agricultural return flow or treated municipal outflow leaving the area.

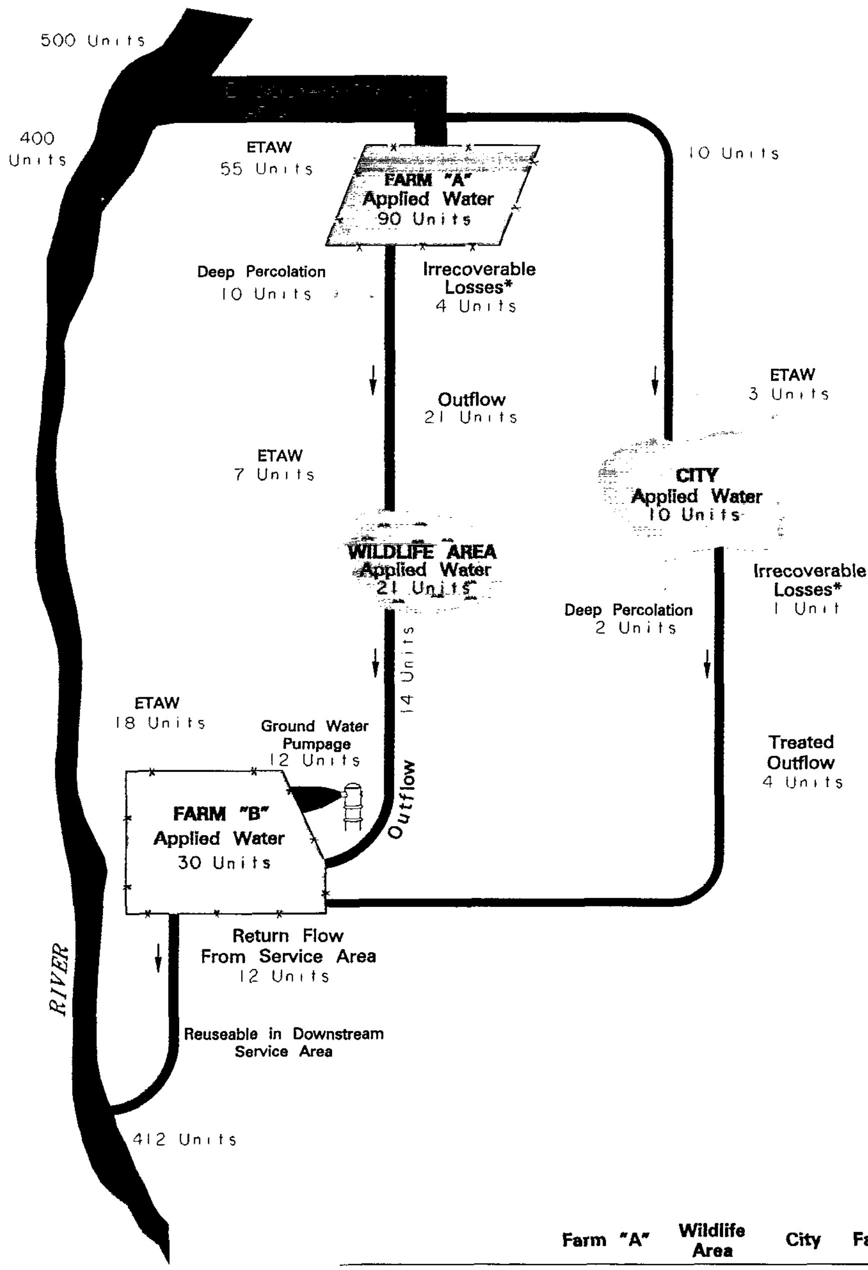
Irrecoverable Losses: The water lost to a salt sink or lost by evaporation or evapotranspiration from a conveyance facility, drainage canal, or in fringe areas.

Depletion: The water consumed within a service area and no longer available as a source of supply. For agriculture and wetlands, it is ETAW (and ET of flooded wetlands) plus irrecoverable losses. For urban water use, it is ETAW (water applied to landscaping or home gardens), sewage effluent that flows to a salt sink, and incidental evapotranspiration losses. For instream use, it is the amount of dedicated flow that proceeds to a salt sink.

Figures III-A through III-C show examples of how applied water, net water use, and depletion amounts are derived in three different cases. Figure III-A shows how outflow in an inland area is reusable; Figure III-B shows how outflow to a salt sink is not reusable; and Figure III-C shows how outflow in an inland area is reusable when agricultural water use is more efficient.

Figure III-A. Derivation of Applied Water, Net Water Use, and Depletion

Example of Water Use in Inland Areas



	Farm "A"	Wildlife Area	City	Farm "B"	TOTAL
Applied Water	90	21	10	30	151
Reuse Water	31	14	6	0	51
Net Water Use	—	—	—	—	100
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	1	0	5
Depletion	59	7	4	18	88

ETAW = EVAPOTRANSPIRATION OF APPLIED WATER

*Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation of water to saline sinks.

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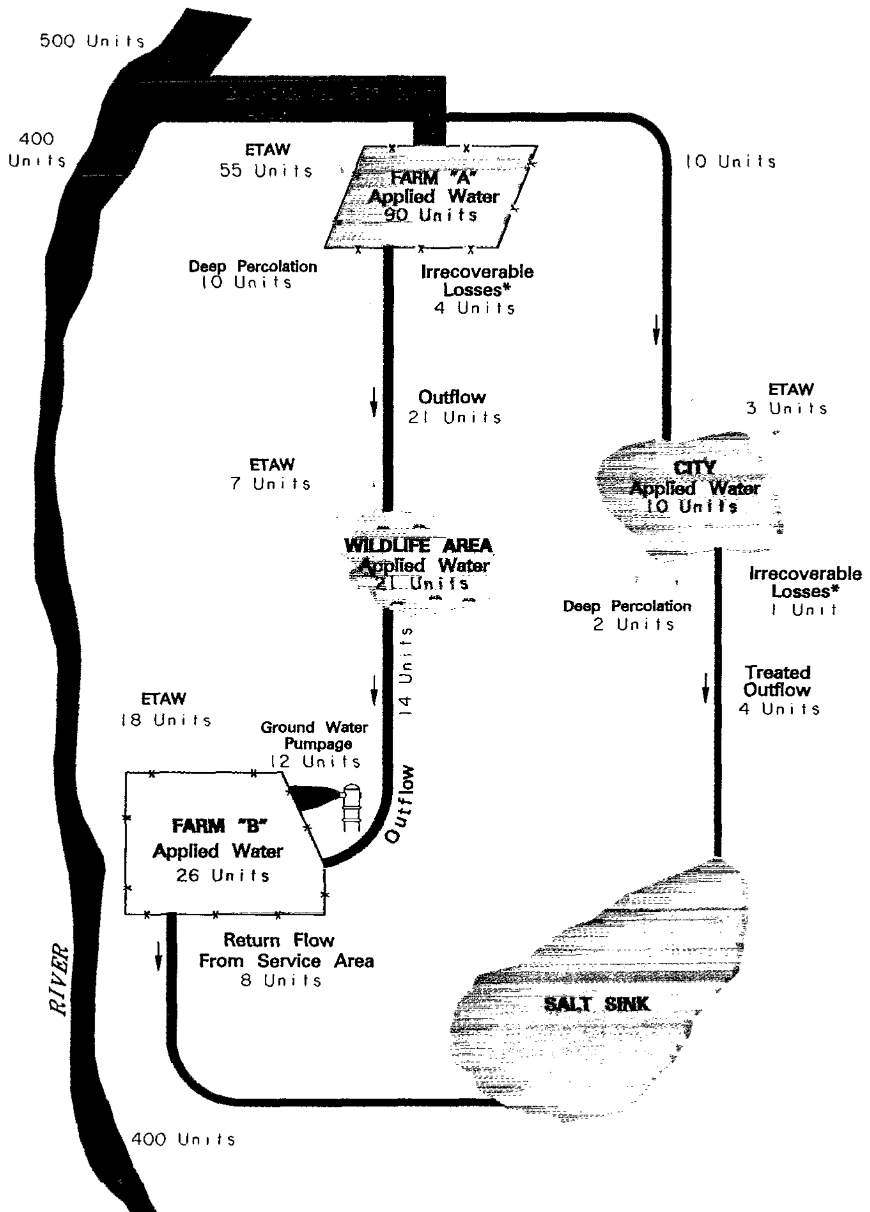
Figure III-B. Derivation of Applied Water, Net Water Use, and Depletion

Example of Area with Salt Sink



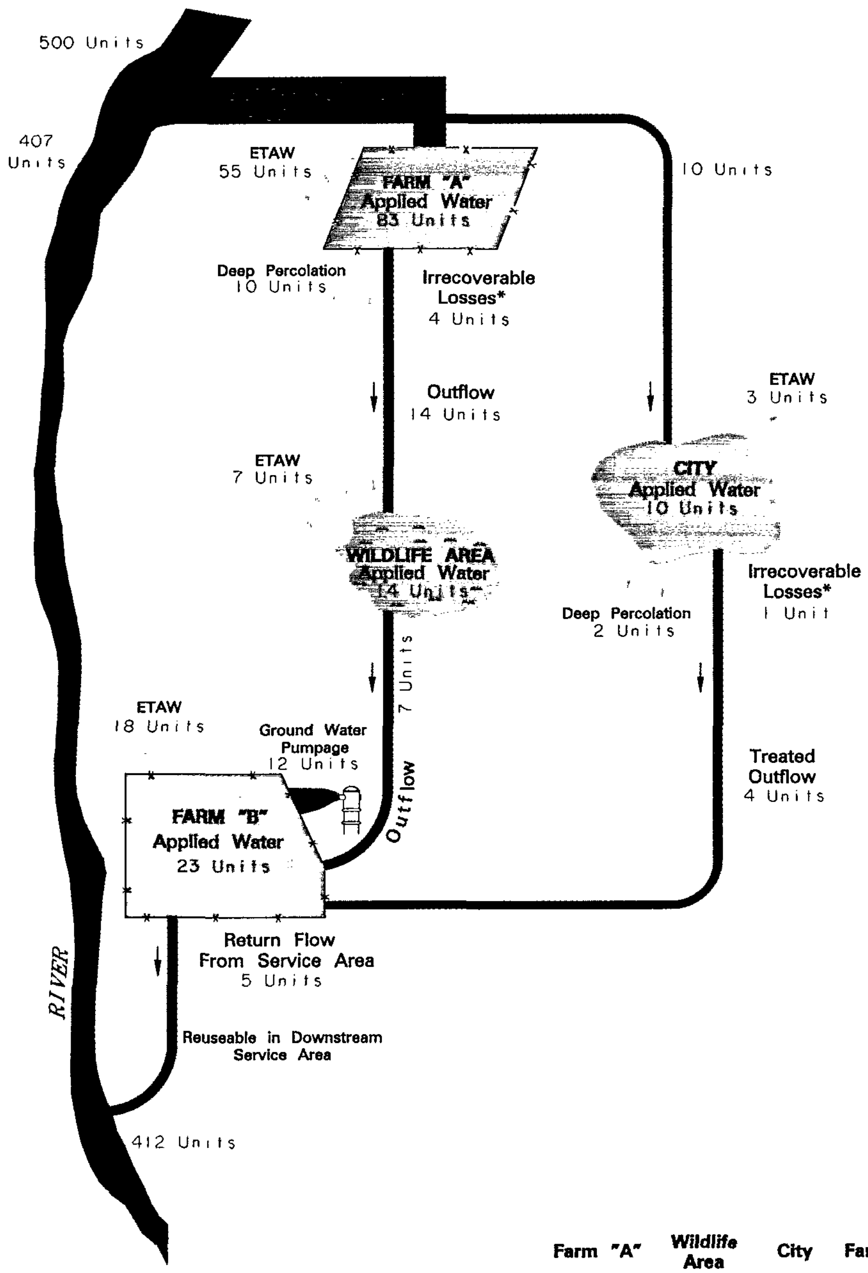
	Farm "A"	Wildlife Area	City	Farm "B"	TOTAL
Applied Water	90	21	10	26	147
Reuse Water	31	14	2	0	47
Net Water Use	—	—	—	—	100
ETAW	56	7	3	18	83
Irrecoverable Losses*	4	0	5	8	17
Depletion	59	7	8	26	100

ETAW = EVAPOTRANSPIRATION OF APPLIED WATER

*Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation of water to saline sinks.

Figure III-C. Derivation of Applied Water, Net Water Use, and Depletion

Example of Most Inland Areas with High Efficiency



	Farm "A"	Wildlife Area	City	Farm "B"	TOTAL
Applied Water	83	14	10	23	130
Reuse Water	24	7	6	0	37
Net Water Use	—	—	—	—	93
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	1	0	5
Depletion	59	7	4	18	88

ETAW = EVAPOTRANSPIRATION OF APPLIED WATER

*Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation of water to saline sinks.

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Xeriscaping, designing landscapes that incorporate low-water-using plants, is an effective means of reducing landscape irrigation. As shown by this xeriscape in Riverside County, the designs use a variety of plants—not just succulents or cacti.

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Chapter 6

Urban Water Use

Urban water use is generally determined by population, its geographic location, and the percentage of water used in a community by residences, industry, government, and commercial enterprises. It also includes water that cannot be accounted for because of distribution system losses, fire protection, or unauthorized uses. For the past two decades, urban per capita water use has leveled off in most areas of the State. The implementation of local water conservation programs and current housing development trends, such as increased multiple-family dwellings and reduced lot sizes, have actually lowered per capita water use in some areas of the State. However, gross urban water demands continue to grow because of significant population increases and the establishment of urban centers in the warmer interior areas of the State. Even with the implementation of aggressive water conservation programs, urban water demand in California is expected to grow in conjunction with increases in population.

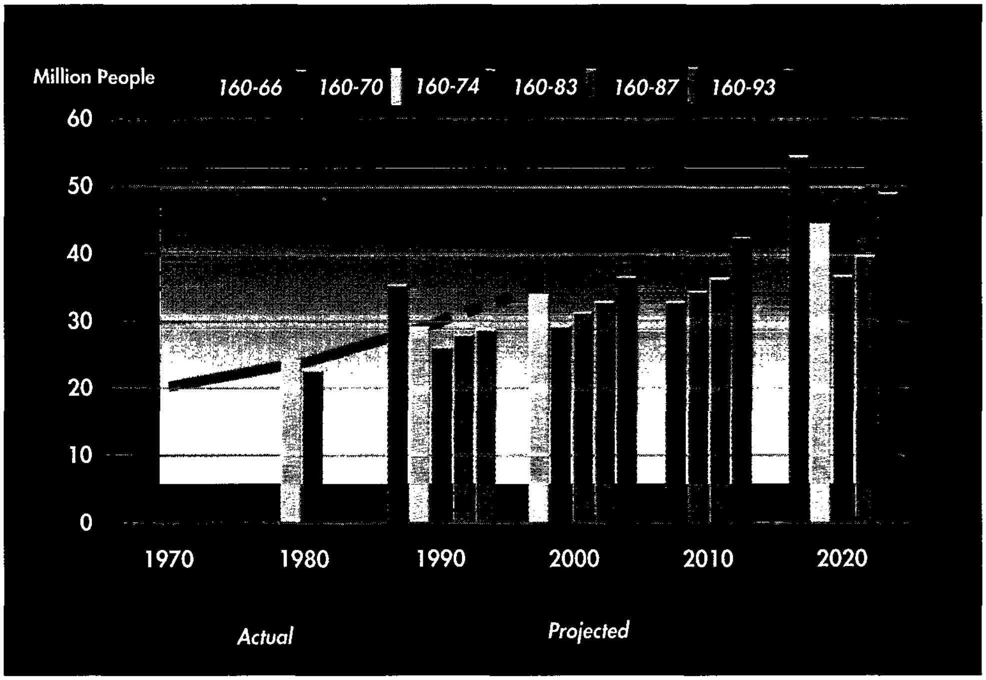
Estimates of urban water use in this update of the California Water Plan are based on population and per capita water use values. per capita values, called unit use values, are estimated from water production and delivery records provided by urban water purveyors. The gross per capita use was divided into residential, commercial, industrial, governmental, and unaccounted categories, and the percentage of total water use represented by each category was calculated. In most cases, the gross per capita water use numbers presented need to be interpreted carefully because high-water-using industries and commercial enterprises can skew the figures. For example, a high-water-using paper pulp mill on the North Coast can double the gross per capita water use for that area. Furthermore, per capita water use values can mask effects of drought, conservation, inland growth, changes in industry, and other factors affecting water use simultaneously.

This chapter presents factors affecting urban water use, including population growth, urban land use, water conservation, and pricing, as well as presenting urban water use forecasts to 2020.

Population Growth

Population growth now exceeds projections made in the 1980s and has continued into the 1990s despite the recent economic recession. Although several entities forecast population growth, State law requires that the Department of Water Resources use Department of Finance population projections for planning purposes. Forecasts of urban water use in this bulletin are based on Department of Finance's *Population Projections by Race/Ethnicity for California and Its Counties, 1990-2040*, Report 93 P-1. Figure 6-1 compares population projections from prior water plan updates. DOF projections use a baseline cohort-component method to project population with assumptions as to future birth rates, death rates, and net migration. Trends based on population estimates back to 1960 were used to calculate the projections reported

Figure 6-1. Comparison of California Population Projections Bulletin 160 Series



here. DOF projections at the county level were used as the control for all DWR projections. Only some Northern California coastal counties, such as San Francisco and Marin, are projected to have little or no growth out to 2020. The 1990 through 2020 population figures, by hydrologic region, are shown in Table 6-1.

For a comparison of projections, Figure 6-2 compares DOF projections to those of the following:

- Southern California—Southern California Association of Governments and San Diego Association of Governments
- San Francisco Bay Area—Association of Bay Area Governments

Urban Land Use

Accompanying the growth in population has been a dramatic increase in urban land use (acreage). Trends in urban land use can cause significant changes in urban

Table 6-1. California Population by Hydrologic Region
(millions)

Hydrologic Regions	*1990*	*2000*	*2010*	*2020*
North Coast	0.6	0.7	0.8	0.9
San Francisco	5.5	6.2	6.6	6.9
Central Coast	1.3	1.5	1.8	2.0
South Coast	16.3	19.3	22.1	25.3
Sacramento River	2.2	2.9	3.5	4.1
San Joaquin River	1.4	2.0	2.6	3.2
Tulare Lake	1.5	2.2	2.8	3.5
North Lahontan	0.1	0.1	0.1	0.1
South Lahontan	0.6	1.0	1.4	1.9
Colorado River	0.5	0.6	0.8	1.0
TOTAL	30.0	36.5	42.5	48.9

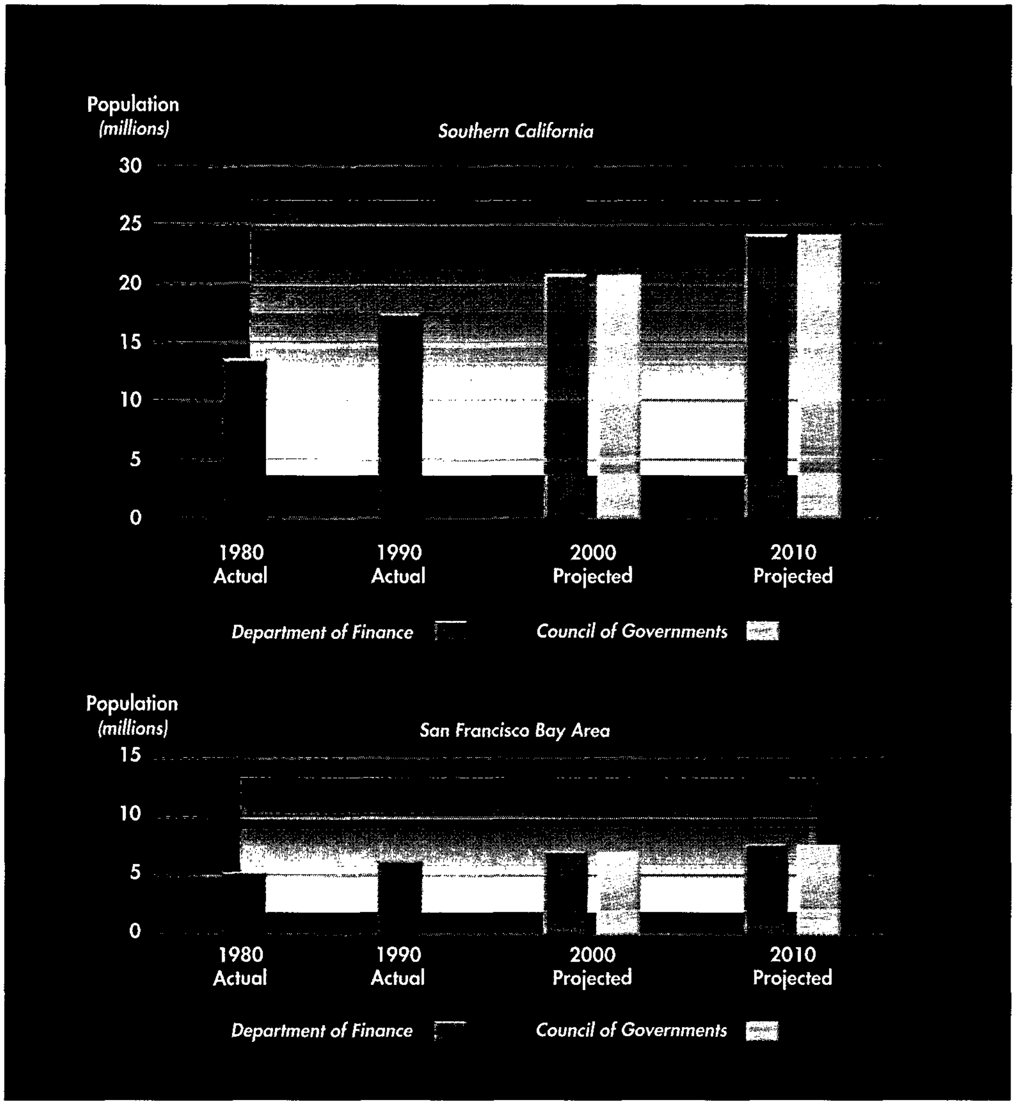


Figure 6-2. Comparison of Department of Finance and Council of Governments Population Projections for California's Two Largest Metropolitan Areas

per capita water use. For example, smaller lot sizes and increased multi-family housing generally lower per capita water use. Also, increased plantings of low-water-using landscapes and more efficient watering tend to push per capita water use down. However, water conservation efforts have only managed to slow increases in the applied urban water demand because of significant population increases and growth in the State's warmer interior. Based on DWR land use surveys conducted during the 1980s, there are now 3.75 million urban acres in California. Table 6-2 compares California's overall population density with New York, Texas, Florida, and countries with similar levels of industrial development.

With regard to the urbanization of agricultural lands, the Department of Conservation has estimated that nearly 310,000 acres were developed and urbanized between 1984 and 1990. Of this land, 63,400 acres were formerly irrigated farmland, over one-half of which was considered prime farmland, according to the U.S. Department of Agriculture's Land Inventory and Monitoring System as modified for California.

Table 6-2. 1990 Population Densities of Selected States and Countries

State/Country	Population	Area (square miles)	Density (population/sq. mi.)
California	29,760,000	155,973	191
Florida	12,938,000	53,997	240
New York	17,990,000	47,224	381
Texas	16,987,000	261,914	65
Germany	79,113,000	137,822	574
Netherlands	14,944,000	13,103	1,141
Japan	123,612,000	145,875	847
United Kingdom	57,411,000	93,643	613
France	56,614,000	210,026	270

Urban Water Conservation

Urban water conservation efforts have been expanding since the 1970s. Unlike agriculture, organizations such as the University of California Cooperative Extension and local Resource Conservation Districts did not exist to provide conservation expertise to urban water users. Urban water agencies have now filled that void and are dramatically increasing water conservation programs. DWR's Water Conservation Office works cooperatively with local water agencies on many conservation efforts such as leak detection, plumbing code changes, conservation planning, efficient landscape ordinances, and Best Management Practices. DWR's Water Education Office, with assistance from district offices, is working with local agencies to develop and implement water education programs.

With the passage of the Urban Water Management Planning Act in 1983, the California Legislature acknowledged the importance of water conservation and demand management as essential components of water planning. The act requires the 300 medium–sized and large urban water agencies to prepare and adopt plans for the efficient use of their water supplies and update those plans every five years. The first plans were due in 1985. Over 95 percent of the agencies affected by the law submitted a plan.

In 1988, during the Bay–Delta Proceedings, interested parties gave the State Water Resources Control Board widely divergent opinions on appropriate levels for implementing urban conservation measures. To resolve these differences, urban water agencies, environmental groups, and State agencies actively participated in a three–year effort which resulted in identifying Best Management Practices. These are conservation measures that meet either of the following criteria:

- An established and generally accepted practice among water suppliers that results in more efficient use or conservation of water.
- A practice for which sufficient data are available from existing water conservation projects to indicate that significant conservation or conservation-related benefits can be achieved; the practice is technically and economically reasonable, environmentally and socially acceptable, and not otherwise unreasonable for most water suppliers to carry out.

Sixteen initial BMPs that meet at least one of these criteria have been identified. Table 6-3 lists the practices and indicates those that have been quantified. Several additional practices that may meet the criteria are under study as Potential Best Man-

Table 6-3. Best Management Practices for Urban Water Use

Management Practice	*Estimates of Water Savings*	
	Quantified	*Not Quantified*
1. Interior and Exterior Water Audits and Incentive Programs for Single Family Residential, Multi-Family Residential, and Governmental/Institutional Customers	x	
2. New and Retrofit Plumbing	x	
3. Distribution System Water Audits, Leak Detection, and Repair	x	
4. Metering with Commodity Rates for All New Connections and Retrofit of Existing Connections	x	
5. Large Landscape Water Audits and Incentives	x	
6. Landscape Water Conservation Requirements for New and Existing Commercial, Industrial, Institutional, Governmental, and Multi-Family Developments	x	
7. Public Information		x
8. Water Education Programs for Schools		x
9. Commercial and Industrial Water Conservation	x	
10. New Commercial and Industrial Water Use Review		x
11. Conservation Pricing		x
12. Landscape Water Conservation for New and Existing Single Family Homes		x
13. Water Waste Prohibition		x
14. Water Conservation Coordinator		x
15. Financial Incentives		x
16. Ultra-Low Flush Toilet Replacement Programs	x	

agement Practices. The Potential BMPs have not been used in estimating future urban water demand, but are discussed more fully in the last section of this chapter.

As of December 1992, over 100 water agencies, plus over 50 public advocacy groups and other interested parties, had signed a Memorandum of Understanding Regarding Urban Water Conservation in California. This MOU commits signatories to implement these BMPs at specified levels of effort over the period 1991 to 2001. The water industry and others are working toward the implementation of BMPs through the California Urban Water Conservation Council, established under the MOU. Full descriptions of BMPs, including estimates of savings and implementation schedules, are contained in the MOU.

The widespread acceptance of BMPs in California virtually assures that their implementation will become the industry standard for water conservation programs through 2001 and probably beyond. The BMP process offers great advantages for water agencies. There will be significant opportunities to combine programs on a regional basis to reduce implementation costs and increase effectiveness. In addition to the programs described above, many of the cooperative efforts to help local agencies with urban water conservation programs will focus on implementing BMPs.

Water conservation will undoubtedly continue to play a significant role in managing California's urban water needs. Proven conservation measures will be implemented by more agencies, and new measures will gain greater acceptance. More sophisticated economic analyses will shape the ways that water needs are met or modified. However, as water use continues to become more efficient, agencies will lose flexibility in dealing with shortages.

Urban Water Pricing

Many water conservation specialists think conservation encouraged by water pricing is one of the most important BMPs for reducing urban water use. Many factors influence the water prices levied by urban water agencies. Some of the major ones include the source of the water, methods of transporting and treating it, the intended use, the pricing policies and size of water agencies, and climatic conditions.

The costs of supplying water depend greatly on the source and use of the water. For example, the cost of diverting water from a river and using it on adjacent land can be less than $5 an acre-foot; in contrast, the cost of sea water desalination can exceed $2,000 an acre-foot. Other significant factors influencing the cost of water supplies is the distance the water must be transported from the source to its ultimate place of use and the level of water treatment required to make it usable. For example, the State Water Project delivers supplies both in Northern and Southern California and contracting water agencies must pay the full cost of supply and delivery to their area. Supplies delivered to Southern California must travel through hundreds of miles of aqueducts and be pumped over a mountain range before reaching their final destination. As a result, the costs of these supplies are greater than those delivered farther north because of increased transportation costs. The pricing scheme is much like that of train tickets; for example, the farther you travel, the higher the price of the ticket.

If an agency serves a heavily populated area with a large number of connections per square mile, the average fixed costs and some variable energy costs of serving each customer will tend to be less. Conversely, if the agency serves a sparsely populated area, the average fixed costs of serving each customer are normally higher.

Generally, supplies used for urban purposes cost more than those used for agriculture because urban supply systems are more complex and often involve costly local facilities for system regulation, pressurization, treatment plants, distribution systems, water meters, and system operation (including meter reading and customer billing). In addition, some water rates include costs for waste water treatment. Further, future increased treatment costs could add another $1,000 per acre-foot to urban water costs. However, agricultural water costs are typically assessed at the farm headgate or edge of the property. The rates charged for water supplied to agricultural users do not include the costs incurred by a farmer for labor and equipment to distribute water supplies throughout a farm. These costs often incorporate land preparation, specialized machinery, and complex distribution through canals, pipes, or drip lines.

The policies adopted by various water agencies also significantly affect the final prices consumers pay. For example, some agencies use water rates to fully recover the costs of acquiring and delivering supplies, whereas others use a combination of water rates and local property taxes. Policies concerning the use of water meters and rate structure are also important. Although most urban retail agencies in California use meters to monitor customer use and to levy charges, some (mainly in the Central Valley) do not. Typically, the costs to consumers of using unmetered supplies (with flat rate water charges) are less than if those same supplies were metered. However, in times of drought when water use is reduced, water agencies that have flat rates (water charges independent of use) are not affected by reduced revenues to cover fixed costs.

Where supplies are metered, rate structure becomes important. For example, most agencies have switched from declining block rates (where unit water costs decrease with increasing usage) to either constant or increasing block rates. These rates encourage water conservation. Figure 6-3 shows some of the common urban rate structures.

During years of normal or above-normal precipitation, most agencies' supplies are adequate to meet current demands, and rates remain stable. During droughts, the rates water agencies charge vary depending on reliability and availability of supplies. For example, during the 1987-92 drought, many water purveyors adopted higher rates

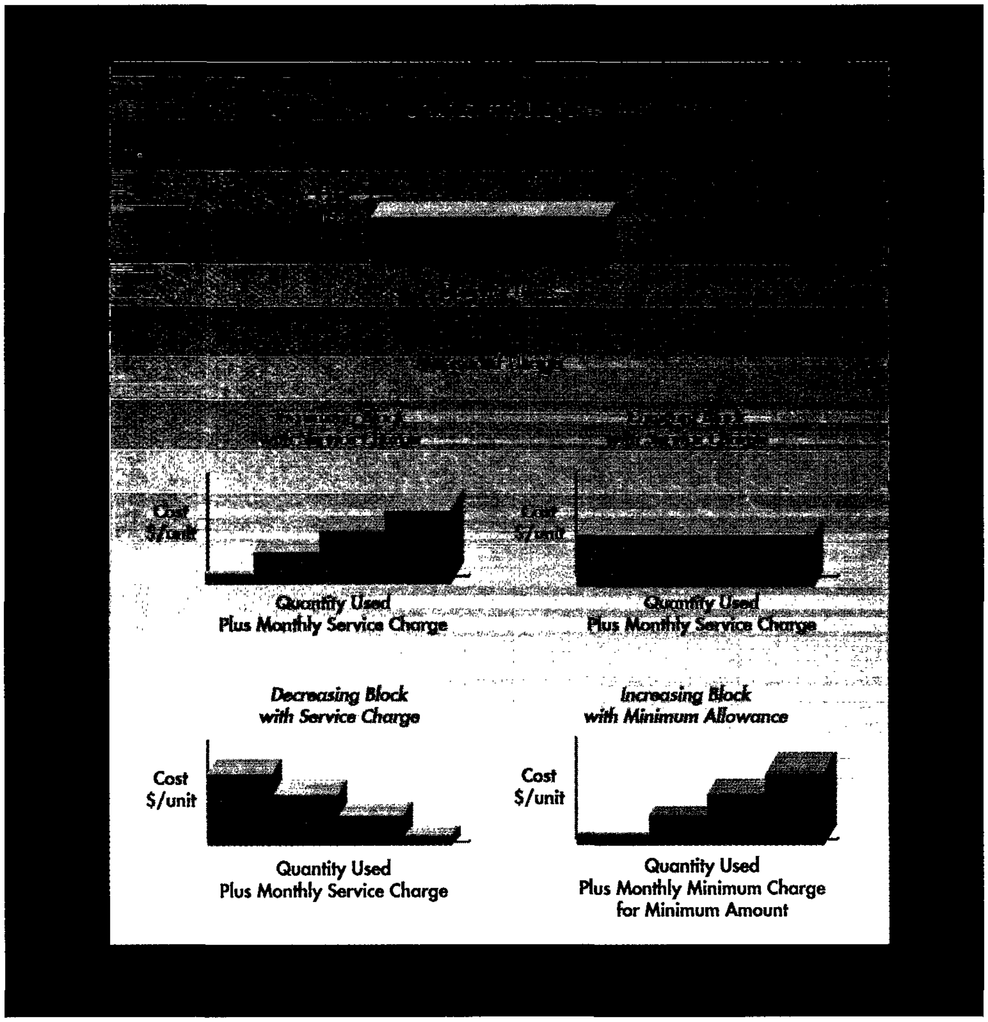


Figure 6-3. Common Urban Water Rate Structures

to encourage water conservation. Several even implemented drought penalty rates designed to drastically reduce water use. These policies reduced water use; however, an unwanted consequence of reduced water use was reduced revenues to the agencies, which still had to pay their system's fixed costs plus the costs of expanded conservation programs. To remain solvent, many water agencies had to increase rates several times during the drought.

The following two subsections discuss urban retail water costs and urban ground water costs. They are presented to illustrate the complexities of urban water pricing and the vast differences in cost to various communities in California.

Urban Retail Water Prices

Urban retail water prices vary greatly because of the large number of agencies with different production costs and pricing policies throughout the State. Each agency is likely to have different pricing policies for the different customer classes, such as residential, commercial, and industrial. Water rates and profit margins of investor-owned utilities in California are regulated by the Public Utilities Commission.

Table 6-4 summarizes 1991 single-family residential monthly use and retail water cost information for selected cities. Some of the higher water bills are found in cities along the coast (such as Corte Madera, Santa Barbara, Goleta, and Oceanside). Some of the lower bills are found in the cities in the Central Valley (such as Sacramento and Fresno). Many of these 1991 water costs are higher than they were prior to the 1987–92 drought.

Table 6-5 summarizes 1991 commercial and industrial water use and cost information for selected cities. Unlike Table 6-4, Table 6-5 does not identify summer and winter uses and costs. Instead, it displays an average monthly use. Single-family residential customers, as a group, tend to have similar unit water uses, which is not the case for commercial or industrial customers. It is difficult to define a typical commercial or industrial customer, particularly in the industrial sector, which can include bakeries as well as oil refineries. Commercial and industrial water costs were based upon a 2-inch meter size. The table shows that some of the higher commercial and industrial water costs are also found along the coast. Some of the lower costs are found

Table 6-4. 1991 Single Family Residential Monthly Water Uses and Costs for Selected Cities[1]

Region/City	Average Summer Monthly Use (ccf)[a]	Average Winter Monthly Use (ccf)[a]	Typical Summer Monthly Bill ($)[b]	Typical Winter Monthly Bill ($)[b]	$ per Acre-foot Cost[b]	Effective Date of Rate
North Coast						
Crescent City	10	8	8	7	369	Jan 1991
San Francisco Bay						
San Francisco	6	6	7	7	484	July 1991
Corte Madera	9	7	34	28	1,688	May 1991
San Jose	23	18	35	28	664	July 1991
Central Coast						
Santa Barbara	7	6	22	18	1,364	May 1991
Goleta	15	9	47	30	1,381	June 1991
Monterey	11	8	31	24	1,160	Jan 1991
South Coast						
Los Angeles	20	10	20	12	462	Jan 1991
Beverly Hills	24	20	28	24	525	Apr 1991
Oceanside	14	11	28	22	875	July 1991
Hemet	15	12	17	15	515	June 1991
Sacramento River						
Sacramento	34	18	10	10	165	July 1991
Chico	17	9	15	15	518	June 1991
Grass Valley	26	13	26	17	484	Jan 1991
San Joaquin River						
Stockton	22	13	14	11	311	May 1990
Tulare Lake						
Fresno	28	12	9	9	193	July 1991
North Lahontan						
Susanville	29	11	27	13	434	Oct 1991
South Lahontan						
Barstow	35	25	29	23	379	Jan 1991
Colorado River						
El Centro	40	30	22	17	244	Sep 1980

(1) Costs shown do not include additional costs, such as property or ad valorem taxes, which increase the real cost of water.
(a) Hundred cubic feet (750 gallons)
(b) Includes service charge

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Table 6-5. 1991 Commercial and Industrial Monthly Water Uses and Retail Costs for Selected Cities

Region/City	Commercial: Average Monthly Use (ccf)[a]	Commercial: Number of Accounts	Commercial: Typical Monthly Bill ($)[b]	Commercial: $ per Acre-foot Cost[b]	Industrial: Average Monthly Use (ccf)[a]	Industrial: Number of Accounts	Industrial: Typical Monthly Bill ($)[b]	Industrial: $ per Acre-foot Cost[b]
North Coast								
Crescent City	73	441	64	379	1,079	8	97	282
San Francisco Bay								
San Francisco	49	22,133	53	471	253	144	208	358
Central Coast								
Santa Barbara	26	2,300	111	1,858	272	65	1,021	1,635
South Coast								
Los Angeles	30	112,472	40	582	703	7,437	104	441
Hemet	67	1,794	77	503	23	359	39	742
Sacramento River								
Chico	62	2,684	46	324	122	41	68	244
San Joaquin River								
Stockton	48	4,000	35	316	1,479	104	673	198
Tulare Lake								
Fresno	70	75	29	183	251	7	78	136
North Lahontan								
Susanville	36	204	55	667	434	14	349	350
South Lahontan								
Barstow	27	8,273	42	672	2,017	6	1,196	258

(a) Hundred cubic feet (750 gallons)
(b) Includes service charge

in the Central Valley. Again, the drought may be have increased these 1991 water costs.

Definitive conclusions concerning water uses and costs among cities cannot be derived solely from these two tables because of the many complex factors influencing water prices, including proximity to supply and the level of treatment required.

Urban Ground Water Prices

Local water agencies provide supplies to most residential and commercial customers in California. Within the industrial sector, small manufacturing firms also obtain supplies mainly from water agencies. However, many large, water-intensive, manufacturing firms (such as refineries and chemical manufacturers) have developed their own ground water supplies.

Ground water costs vary widely throughout the State. Many factors influence these costs, including depth to ground water, electricity rates, pump efficiencies, and treatment requirements. Another factor was the prolonged drought, which resulted in lower ground water levels and higher pumping costs. Typically, self-provided ground water costs are less than the costs of treated surface water. Table 6-6 presents ranges of urban ground water costs for the hydrologic regions. These costs include capital, operations (including pumping energy costs), maintenance, replacement, and treatment costs.

Per Capita Water Use

From the beginning of this century to 1970, urban per capita water use increased steadily, as illustrated by Figure 6-4, which charts increases in per capita water use in

Table 6-6. Typical Urban Ground Water Costs in 1992 by Hydrologic Region

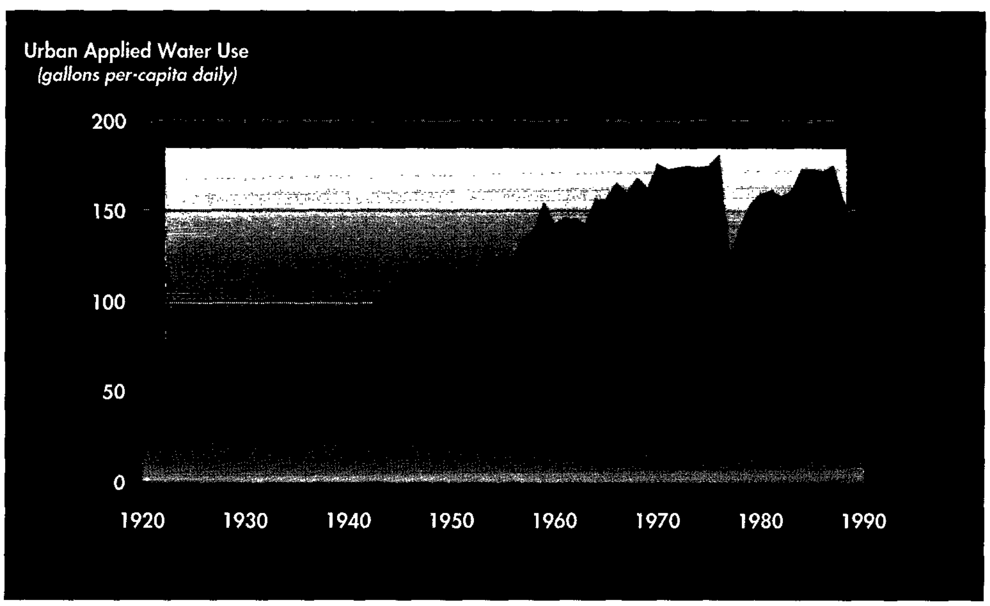
Hydrologic Region	*Ground Water Costs ($/acre-foot)**		
North Coast	75	—	85
San Francisco	85	—	330
Central Coast	200	—	300
South Coast	45	—	190
Sacramento River	50	—	80
San Joaquin River	70	—	270
Tulare Lake	80	—	175
North Lahontan	120	—	190
South Lahontan	85	—	90
Colorado River	115	—	275

*These costs are higher than pumping raw water for agricultural use because capital, operation, maintenance, replacement, and treatment costs are greater.

the San Francisco Bay area. Since 1970, however, the per capita use has been fluctuating but no longer shows a steady increase in most areas of the State, as shown in Figure 6-5, *Urban Per Capita Water Use, 1940–1990*. Large reductions in per capita water use are pronounced during drought years when aggressive short-term conservation and rationing programs are in effect. In the long term, permanent water conservation programs and other factors have begun to reduce overall per capita water use in some areas.

Other factors tend to raise per capita unit use rates, thus making it difficult to analyze trends. Climatic variations affect water use significantly from one year to the next. In the long term, fewer people per household, increases in household income, and population growth in warmer inland areas have tended to counteract the effects of multifamily housing and conservation, which drive per capita water use downward. Figure 6-6 compares the gross average per capita water use in selected California communities from 1980 to 1990. Gross per capita use rates are higher in many hydrologic

Figure 6-4. Urban Per Capita Water Use San Francisco Bay Area 1920–1990



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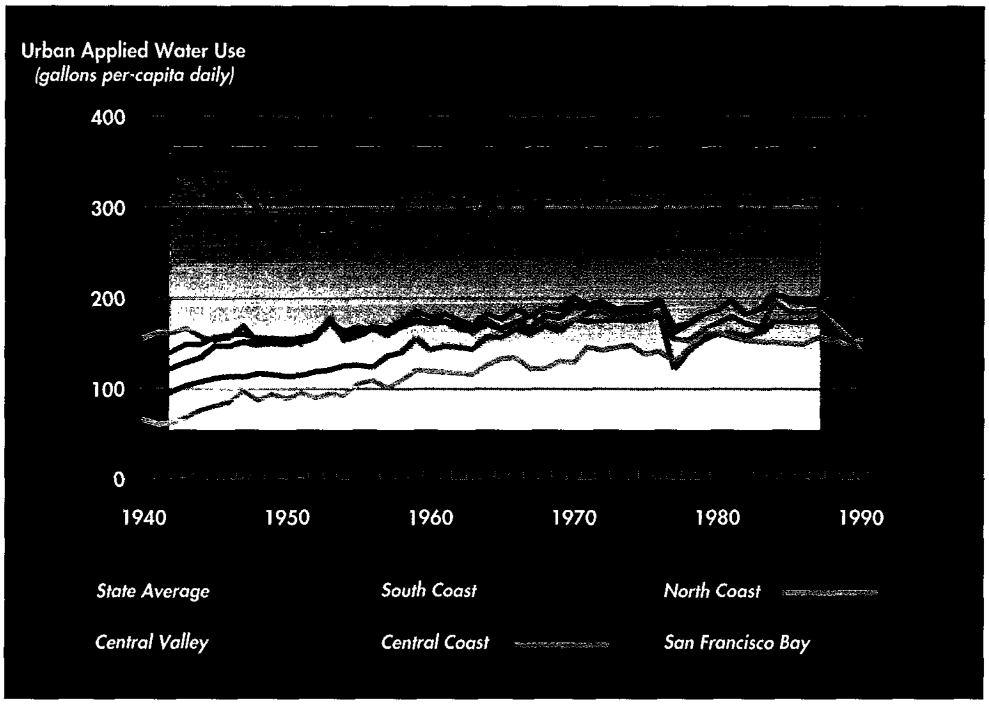
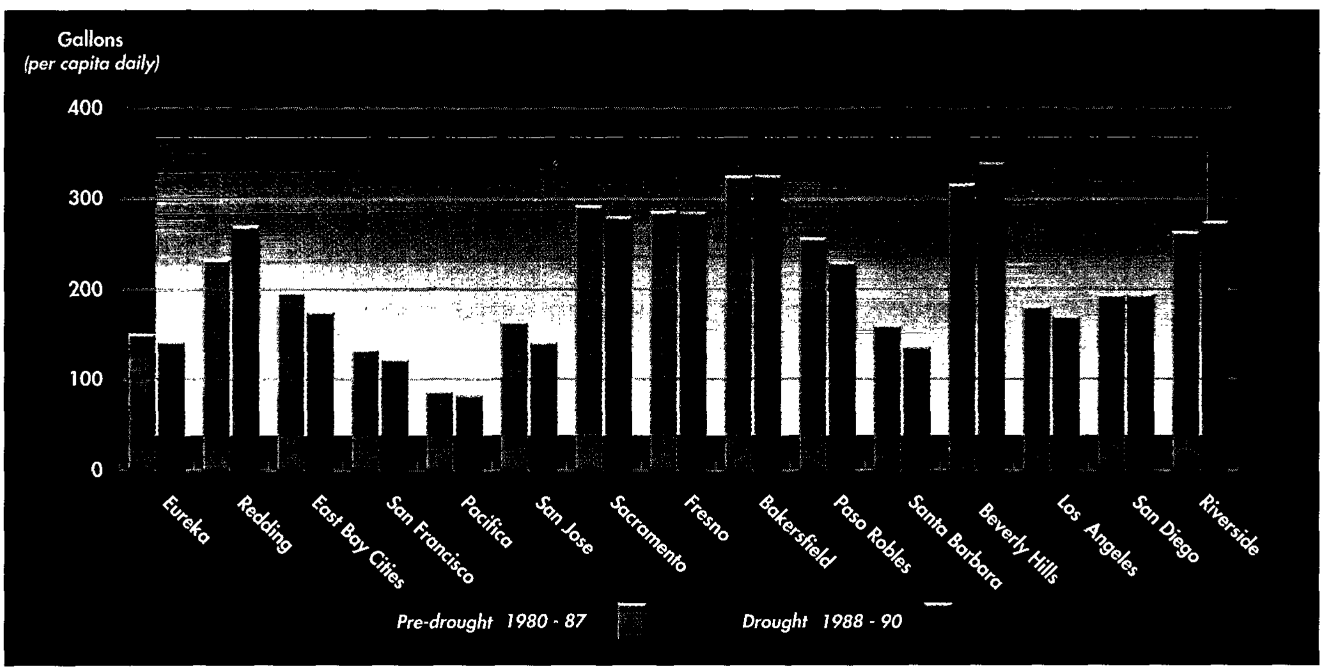


Figure 6-5. Urban Per Capita Water Use 1940–1990

regions because of large industrial or commercial enterprises combined with low resident populations. For example, there are high per capita water use rates in the Colorado River Region because of tourist populations and a predominance of golf courses.

Even with effective drought emergency measures, drier winters tend to cause an increase in water use for landscape irrigation (to replace effective precipitation) during the winter. The average per capita monthly water use, statewide, during the 1987–92 drought, in relation to the rest of the 1980s, illustrates this fact (Figure 6-7).

Figure 6-6. Comparison of Per Capita Water Use by Selected Communities



Gallons per capita daily of total urban applied water use—does not include self-supplied water.

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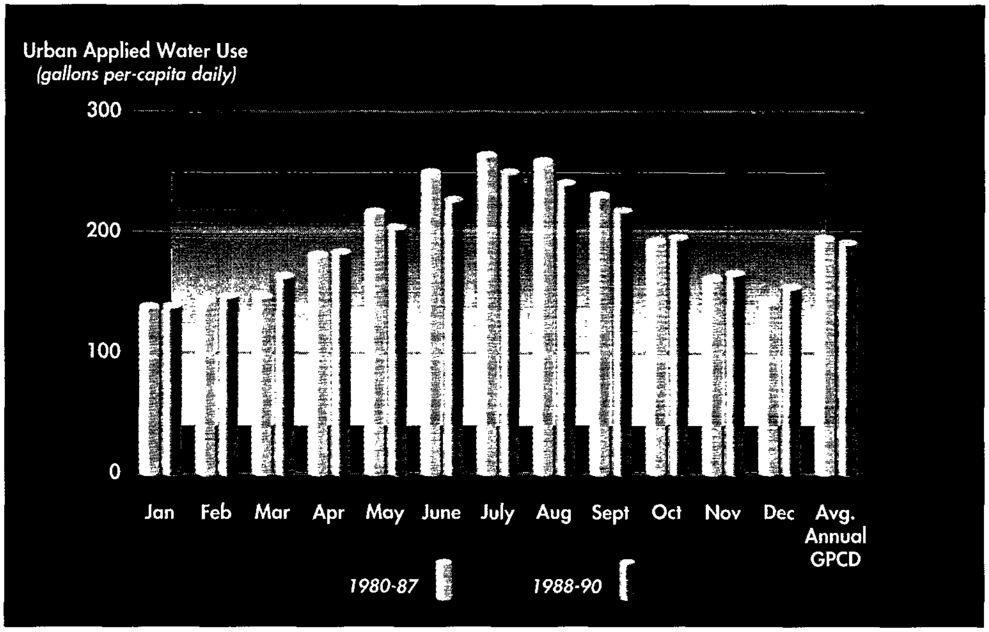
Figure 6-7. Average Monthly Urban Per Capita Water Use Statewide

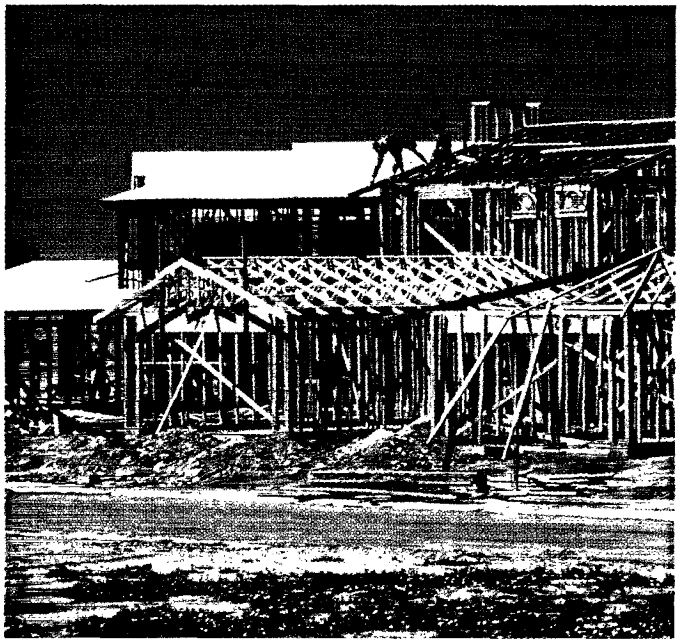
Does not include self-supplied water.



Disaggregating Urban Water Use

The gross per capita water use values previously cited can be separated into the four categories of use: residential, commercial, industrial, and governmental. Percentages of total urban water use have been estimated for these four sectors for 1990 and compared with 1980 in Figure 6-8. The biggest difference is in industrial water use. The decline in industrial water use results from conservation and water reuse undertaken in that sector, as well as the closure of some high-water-using industries, such as lumber mills and canneries. Waste water discharge requirements have caused many industries to recycle their water to avoid the costly water treatment required for discharge.

The population in the Sacramento River Region is expected to double by 2020. New housing construction in the region will continue. With the help of Best Management Practices, such as installing low-flow shower heads and low-flush toilets, the increases in urban water use can be moderated.



Residential water use averages about 120 gallons per capita per day in California. Overall interior water use has remained near 80 gallons per capita per day on the average during the 1980s. However, these per capita figures can vary significantly due to household income and single-family or multifamily households. Table 6-7 shows the breakdown of indoor water use into its components. Exterior water use is extremely

Table 6-7. 1990 Distribution of Residential Interior Water Use

Component	*Average Use, Percentage*
Toilet	36
Bath/Shower	28
Faucets	13
Laundry	20
Dishwashing	3
TOTAL	100

variable, ranging from 30 percent of residential use in coastal areas up to 60 percent in hot inland areas.

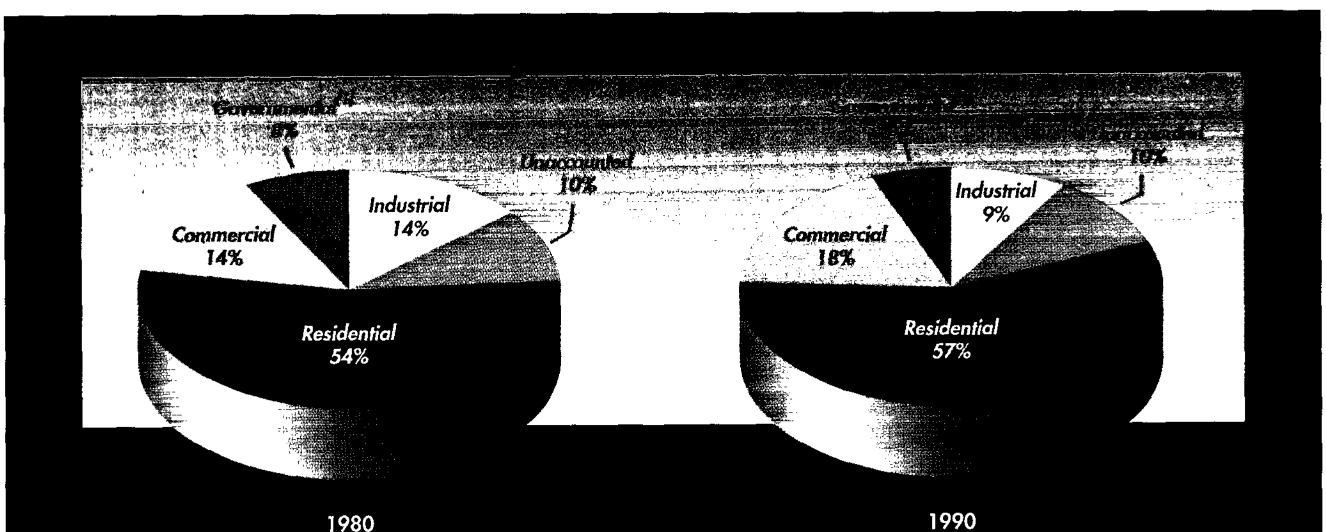
Urban Water Use Forecasts

The 1990 level was normalized using per capita water use values based on an average of 1980 to 1987 per capita use of more than 130 California communities. This "normalization" for the 1990 level was achieved by using water use data not affected by the 1987–92 drought. Those drought years were affected by rationing and mandatory conservation programs. The averages also include estimates of self-supplied (not delivered by water purveyors) ground and surface water. These values were then weighted by population to yield the gallons per capita daily use by region as displayed in Table 6-8. Incorporated in these values are reductions in per capita use, caused by conservation, that have accumulated since 1980. It is estimated that urban applied water in the normalized 1990 base-year was being reduced annually by approximately 435,000 af statewide due to on-going conservation programs as compared to 1980. This estimate did not include drought contingency programs. As mentioned earlier, these are gross per capita water use values that include the residential, commercial, industrial, and governmental sectors; the percentage of current total use for each sector is shown in Table 6-9.

Urban Water Use Forecast to 2020

The forecasted per capita use by hydrologic regions for years 2000 through 2020 shown in Table 6-8 includes estimates of the reductions in urban use caused by imple-

Figure 6-8. Urban Applied Water Use by Sector



(1) Includes irrigation of golf courses, park sites, etc.

Table 6-8. Present and Projected Urban Unit Applied Water by Hydrologic Region
(gallons per capita daily)

Region	1990		2000*		2010*		2020*	
	All Uses	Residential	All Uses	Residential	All Uses	Residential	All Uses	Residential
North Coast	263	137	242	126	230	120	224	118
San Francisco	193	106	186	102	184	100	181	98
Central Coast	189	112	185	110	185	110	185	110
South Coast	211	124	209	123	209	123	209	123
Sacramento River	301	169	283	161	277	156	270	151
San Joaquin River	309	216	300	210	293	206	285	202
Tulare Lake	301	202	295	180	287	175	284	173
North Lahontan	421	160	397	171	387	166	380	163
South Lahontan	278	175	260	165	255	163	255	163
Colorado River	579	336	557	323	557	323	553	321

*Forecasted values including unit use reduction due to BMPs.

mentation of BMPs; these are rough estimates since the range of savings that can be expected from an individual BMP may be quite large. For this bulletin, the estimated reductions due to BMPs range from 7 to 10 percent of the forecasted per capita use, depending on the location of the area studied. The applied water reductions and the depletion reductions in 2020 due to BMPs are shown in Table 6-10. The reductions in depletions stem from reduced landscape evapotranspiration or reduced outflow to the ocean because of reduced interior water use.

The reductions in depletion are greater for coastal cities where waste water is discharged to the ocean and serves no further beneficial use. Applied water reductions in the San Francisco Bay area are all considered reductions in depletions because waste water is discharged to the ocean. In contrast, in the Sacramento River Region most excess applied water either recharges ground water basins or is returned to the river through waste water treatment facilities for later reuse downstream and thus is not a depletion. For example, the depletion resulting from net water demand in Sacramento versus that of Walnut Creek is 146 gallons per capita daily versus 184 gallons per capita daily, respectively.

Table 6-9. 1990 Percentage of Urban Water Use by Sector

Region	Residential	Commercial	Industrial	Governmental	Unaccounted
North Coast	52	15	14	5	14
San Francisco	54	22	9	7	8
Central Coast	60	16	8	6	10
South Coast	59	18	8	6	9
Sacramento River	56	17	6	12	9
San Joaquin River	70	8	10	6	6
Tulare Lake	67	10	10	4	9
North Lahontan	38	19	26	10	7
South Lahontan	63	13	1	13	10
Colorado River	59	22	2	3	14
Statewide	58	17	8	7	10

Table 6-10. Applied Urban Water Reductions and Reductions in Depletions by Hydrologic Region
(thousands of acre-feet)

Region	*Applied Water Reductions*	*Depletion Reductions*
North Coast	65	55
San Francisco	250	250
Central Coast	30	30
South Coast	610	490
Sacramento River	110	25
San Joaquin River	60	20
Tulare Lake	65	20
North Lahontan	5	0
South Lahontan	50	10
Colorado River	40	35
TOTAL	1,285	935

Of course, the total urban applied water, net water demand, and depletions will continue to increase to 2020 because of population growth. An even greater increase is expected in drought years because of less rainfall recharging soil moisture in urban landscapes. Table 6-11 presents the estimated increases in statewide urban water demand from 1990 to 2020.

When the potential BMPs summarized in Table 6-12 are approved by the California Urban Water Conservation Council, they will be analyzed and are expected to provide some additional urban water demand reduction. For this report, the reduction in demand due to potential BMPs was not quantified. However, these potential BMPs are not expected to provide as much demand reduction as those BMPs already adopted, primarily because the potential BMPs identify few practices that affect exterior water use where the largest potential for future urban water savings exists.

Recommendations

Urban water agencies recognize the need for better demand forecasting methods to estimate water use. Some water agencies are moving toward a more disaggregated approach, similar to that of energy utilities. DWR and the University of California at Los Angeles have evaluated forecasting methods and developed procedures to estimate conservation from BMPs. In this approach, more data, much of which is currently unavailable or goes unreported about the end uses of water must be analyzed individually and then aggregated together to forecast overall water use. At a minimum, water use information must be known about the following categories: single-family residential; multi-family residential; commercial/institutional; industrial; and public/unaccounted. Other information on household population density, household income, and pricing structure is necessary as well. The demand must also be analyzed for winter (baseline) use and summer (peak) use. The water demand without conservation is then calculated. An expected range of demand reductions due to conservation is then estimated for each BMP. The median value of each range can be used to estimate a percentage reduction in the forecasted demand without conservation for each BMP. For many BMPs, particularly those affecting exterior water use, there are widely divergent appraisals of water savings that will need further study to improve the quality of such estimates. Specific recommendations are as follows:

1. Urban water use forecasts require annual reporting of data to accurately estimate urban water use for residential, industrial, commercial, and

Table 6-11. Urban Water Demand by Hydrologic Region
(thousands of acre-feet)

Hydrologic Region	*1990* average	*1990* drought	*2000* average	*2000* drought	*2010* average	*2010* drought	*2020* average	*2020* drought
North Coast								
Applied water demand	168	177	186	195	204	214	219	230
Net water demand	168	177	186	195	204	214	219	230
Depletion	110	112	119	122	127	132	136	142
San Francisco Bay								
Applied water demand	1,186	1,287	1,298	1,390	1,365	1,486	1,406	1,530
Net water demand	1,186	1,287	1,298	1,390	1,365	1,486	1,406	1,530
Depletion	1,079	1,175	1,185	1,271	1,247	1,362	1,287	1,403
Central Coast								
Applied water demand	273	277	315	321	365	373	420	429
Net water demand	229	233	263	268	304	311	349	357
Depletion	203	206	235	239	272	278	315	321
South Coast								
Applied water demand	3,851	3,997	4,446	4,617	5,180	5,381	6,008	6,244
Net water demand	3,511	3,641	4,010	4,161	4,623	4,799	5,309	5,514
Depletion	3,341	3,463	3,536	3,677	3,993	4,158	4,596	4,785
Sacramento River								
Applied water demand	744	807	911	989	1,076	1,167	1,231	1,335
Net water demand	744	807	911	989	1,076	1,167	1,231	1,335
Depletion	236	257	293	318	349	378	400	434
San Joaquin River								
Applied water demand	495	507	663	684	839	867	1,029	1,063
Net water demand	353	366	468	490	587	616	717	752
Depletion	192	194	258	265	332	340	410	420
Tulare Lake								
Applied water demand	523	523	716	716	892	892	1,116	1,116
Net water demand	214	214	292	292	364	364	454	454
Depletion	214	214	292	292	364	364	454	454
North Lahontan								
Applied water demand	37	38	43	44	46	48	51	52
Net water demand	37	38	43	44	46	48	51	52
Depletion	14	15	17	18	19	20	21	21
South Lahontan								
Applied water demand	187	193	292	302	409	423	550	565
Net water demand	123	125	191	198	269	277	360	372
Depletion	123	125	191	198	269	277	360	372
Colorado River								
Applied water demand	301	301	399	399	512	512	621	621
Net water demand	204	204	272	272	349	349	424	424
Depletion	204	204	272	272	349	349	424	424
TOTAL								
Applied water demand	7,800	8,100	9,300	9,700	10,900	11,400	12,700	13,200
Net water demand	6,800	7,100	7,900	8,300	9,200	9,600	10,500	11,000
Depletion	5,700	6,000	6,400	6,700	7,300	7,700	8,400	8,800

Table 6-12. Potential Best Management Practices

1. Rate structures and other economic incentives and disincentives to encourage water conservation.
2. Efficiency standards for water using appliances and irrigation devices.
3. Replacement of existing water using appliances (except toilets and showerheads whose replacements are incorporated as Best Management Practices) and irrigation devices.
4. Retrofit of existing car washes.
5. Graywater use.
6. Distribution system pressure regulation.
7. Water supplier billing records broken down by customer class (e.g., residential, commercial, industrial).
8. Swimming pool and spa conservation including covers to reduce evaporation.
9. Restrictions or prohibitions on devices that use evaporation to cool exterior spaces.
10. Point-of-use water heaters, recirculating hot water systems, and hot water pipe insulation.
11. Efficiency standards for new industrial and commercial processes.

governmental sectors. Water use data reported to the State Controller's Office and the Department of Health Services, Office of Drinking Water, are currently insufficient to meet increasingly more complex forecasting needs. DWR should implement new reporting mechanisms for urban water use data.

2. Local land use planning and resulting General Plans should be coordinated with water resources planning agencies to insure compatibility between land use plans and water supply plans to make optimum use of the State's water resources.

3. DWR, in cooperation with the Urban Water Conservation Council, should determine cost-effectiveness and water savings (reduced depletions) resulting from the various urban Best Management Practices and identify additional urban practices for use in statewide and regional planning.

4. Urban "water price" effects and their relationship to conservation practices are not well understood and require further data collection and analysis to ascertain the effect on demand. It is recommended that efforts of the Urban Water Conservation Council and others be combined with an expanded program in DWR to address the issue.

C-037800

Salinas Valley lettuce; California grown lettuce accounted for 75 percent of the lettuce produced in the U.S. in 1990.

C—037801

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Chapter 7

Agricultural Water Use

Agricultural water use is generally determined by the extent of irrigated acreage, the relative proportions of types of crops grown, climatic conditions, and irrigation efficiency. Up until the early 1980s, irrigated crop lands in California were expanding. Today, however, economic uncertainties are more pronounced, and views differ widely over the magnitude and direction of major forces that will shape crop markets in the coming decades. Furthermore, uncertain and often more costly water supplies are affecting the continuous economic viability of some irrigated lands, primarily on the west side of the San Joaquin Valley and in the South Coast Region. Figure 7-1 compares irrigated acreage projections from prior water plan updates. This chapter examines factors that affect agricultural water use including: import and export markets; crop water use; irrigation management; drainage and salinity; water price and production costs; and agricultural water conservation. It then presents estimates of 1990 agricultural water use and forecasts to 2020.

As recently as 1990, California enjoyed a sizable export capability by producing nearly 50 percent of the nation's fruits, nuts, and vegetables. Yet California's population is only 12 percent of the nation's total. California's 31 million acres of farmland, of which nearly one-third is irrigated, accounts for only 3 percent of the country's farmland but produces about 11 percent of the total U.S. agricultural value. California agriculture is considered one of the most diversified in the world with over 250 different crops and livestock commodities, with no one crop dominating the State's farm economy. This modern and highly technological $20-billion-a-year industry not only

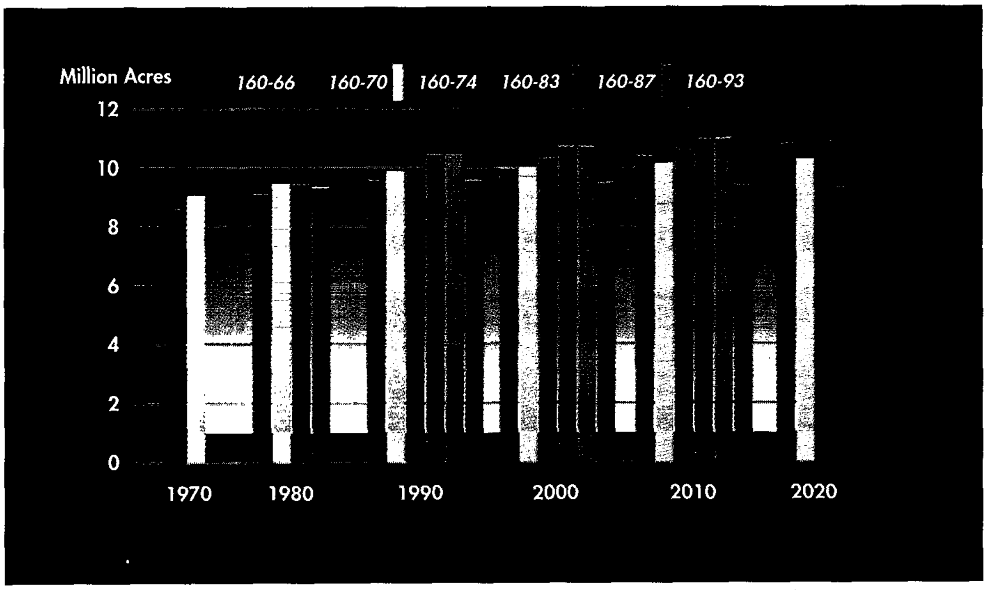

Figure 7-1. Comparison of Irrigated Acreage Projections Bulletin 160 Series

provides many of the State's jobs but also provides Californians with relatively low-cost food and fiber while serving as the backbone of California's rural economy.

But times are changing. The 1987-92 drought, the Central Valley Project Improvement Act of 1992, and recent actions to protect fisheries in the Delta have changed the outlook for irrigated agriculture. Agricultural water service reliability has changed dramatically. The frequency and severity of shortages will become increasingly difficult to manage. Furthermore, over 300,000 acres of irrigated agricultural land may be urbanized by a population growing from 30 million in 1990 to 49 million by 2020. Even though California agriculture may continue to increase in terms of total value, become even more efficient, and produce higher yields per acre, California's output of some crops, such as alfalfa, lags substantially behind the nation's growing need for these crops.

This water plan update forecasts a net decline of nearly 400,000 irrigated acres. For the first time, international crop market competition, increasing yields on existing land, and water supply cost and availability are expected to be constraints to putting new land into irrigated agriculture. Most irrigated acreage being lost to urbanization or lying fallow because of drainage problems will not be replaced. Some crops, primarily field crops, are expected to drop in terms of planted acres; others will increase in acres but will decline substantially in market share as the international market grows. Between now and 2010, the balance between world population and level of international crop production is not expected to raise the world prices of grains or fiber to the extent that this trend would be reversed. Because of competitive advantages, most of California's high-return crops, which include fruits, nuts, and vegetables, are expected to be able to take advantage of increased world affluence and, consequently, increased demand for these types of crops.

Table 7-1. Crop Yields in California
(average yields in tons per acre)

Crop	*1960-62*	*1969-71*	*1980-82*	*1989-91*	*Percent Increase 1960/62-1989/91*
Cotton	0.53	0.41	0.54	0.61	15.1
Rice	2.36	2.70	3.42	3.88	64.4
Corn, grain	2.71	2.65	3.69	4.48	65.3
Wheat	0.80	1.20	2.44	2.45 (a)	206.0
Alfalfa	5.10	5.60	6.47	6.65 (b)	30.4
Processed tomatoes	17.12	22.9	25.10	30.90	80.7
Lettuce	9.20	11.00	14.70	17.00	84.8
Oranges	7.10	9.40	11.60	13.80 (c)	94.4
Avocados	1.92	2.83	3.01	—.— (d)	56.8
Prunes (dried)	1.73	1.39	2.16	2.39	38.2
Almonds (shelled)	0.37	0.51	0.55	0.90	76.4
Wine grapes	5.46 (e)	5.22	7.09	7.53	37.9
SIMPLE AVERAGE					70.9

(a) Value is for 1991—widespread drought-induced failure of dryland wheat pulled down the average for 1989 and 1990. With those years included, the average becomes 2.37. Irrigation of wheat also became more prevalent in the 1970s and 1980s.
(b) For 1989 and 1990 only—1991 data unavailable.
(c) Excluding the freeze-damaged year of 1991, where yields were only about a third of the previous years.
(d) Changing avocado varieties, plus the recent freeze and drought, have caused the 1989-91 average yield to be even lower than the 1960-62 average. Therefore, the percent change is for the 1960-62 to 1980-82 period.
(e) For 1965-67—the earliest data available.

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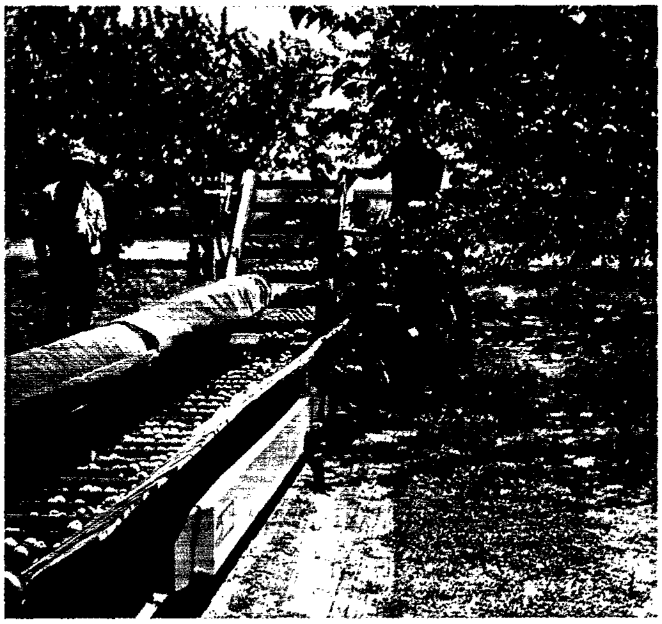

Apple harvesting in the Central Valley. California's Mediterranean climate, long, dry growing season, available irrigation water, and productive soils allow farmers to produce high-value fruits, nuts, and vegetables.

Californians process or directly consume less than 50 percent of the State's farm product. Foreign and domestic exports of California farm products are over three times the value of foreign and domestic farm products imported into California.

This bulletin does not address such public policy issues as government intervention in agriculture to manage wa-ter availability and cost with the objective of maintaining or enhancing market competitiveness for California crops. Such action could benefit the producers of crops declining in acres or market share, as well as associated agricultural businesses, and could also benefit consumers who face higher food prices for some of the affected crops. However, such intervention would likely impose higher costs on other sectors of the California economy.

In any case, California agriculture will remain a major business in the State, helping provide food and fiber for growing populations and helping meet the increasing demand for fruit, nut, and vegetable crops within the U.S. as well as in nations with increasingly affluent citizens. Indeed, because of increasing yields and the expected shift to higher-return crops, as international demand for specialty crops increases, the size of California's farm revenues can be expected to grow substantially.

High yields are achieved in California largely because of efficient management practices, a long growing season, and available irrigation water. These factors, plus soils with desirable characteristics for certain crops and suitable microclimates, also allow for efficient crop production of high-value tree and vine crops. Although yield increases have slowed in the last ten years, the 71-percent simple average yield increase shown in Table 7-1 is impressive testimony to the productivity of California farmers.

In recent years, 22 California crops, covering about 2,760,000 irrigated acres, influenced or dominated the U.S. market and produced an average yearly gross revenue of about $6.74 billion. These are the crops for which most California growers enjoy a strong competitive advantage (for at least certain varieties of the crops) over competing growers in other states. Table 7-2 lists these 22 crops for which California farmers accounted for at least 36 percent of U.S. production of that crop during 1989 through 1991 (based on *California Agriculture, Statistical Review*, reports for 1989, 1990, and 1991, California Department of Food and Agriculture).

Table 7-3 shows how important exports are to the producers of a different list of 23 California agricultural commodities. More than half the California production of four of those crops are exported. In recent years, an average of slightly more than 2 million acres were used to grow those 23 crops for export.

Table 7-2. Irrigated Crops Where California Influences or Dominates the U.S. Market

(California Share of U.S. Population in 1990 = 12.0 Percent
All Figures are 1989-91 Averages)

Crop	CA Share of U.S. Production (Percent)	Acres (Thousands)	Gross Value ($ Millions)
Asparagus	43	36	72
Broccoli	90	96	235
Carrots	58	57	200
Celery	73	23	163
Lettuce	75	161	651
Cantaloupes*	49	83	156
Processed tomatoes	90	299	609
Almonds	100	400	542
Avocados	83	75	213
Grapes	91	639	1,575
Lemons	81	48	224
Nectarines	97	25	88
Olives	100	30	54
Peaches	66	54	187
Pistachios	100	50	95
Plums	85	42	109
Prunes	100	78	159
Strawberries	78	20	417
Walnuts	99	180	244
Oranges*	34	176	500
Alfalfa seed	38	69	48
Safflower*	77	118	45
TOTALS		2,759	6,738

*Average for 1989 and 1990 only; 1991 data unavailable. Note: The criteria for selection to this list is having had, for at least one of the three years, at least 36 percent of U.S. production and at least 20,000 harvested acres in California.

No statistics on consumption of imported agricultural products by Californians are available. However, the U.S. Department of Agriculture does compile statistics (*1991 Agricultural Statistics*) on imports into the U.S. of certain crops and crop groups that compete with California crops. Tables 7-4 and 7-5 give the latest USDA statistics on values and quantities of certain agricultural imports. If California growers of any of these crops do not maintain their share of production to meet rising domestic demand, either because of market incentives or resource constraints, the shortfall likely will be made up with additional imports as well as increases in production in other states, possibly at increased market prices for some crops.

Factors Affecting Agricultural Water Use

The primary factor in California's robust agricultural production has been the abundance of natural resources. Production of irrigated crops depends on carbon dioxide (found naturally in the atmosphere), sunshine, water, nutrients, and soil. These crops in turn produce food, fiber, and oxygen. The water used by the crop is termed consumptive use but the process is actually the conversion of resources to agricultural commodities that are ultimately consumed by the population in general.

Table 7-3. 1990 California Agricultural Export Data

Crop	Value of CA Exports ($ millions)	Acres Needed to Produce CA Exports (thousands)	Exported Share of CA Production (percent)
Cotton lint	755	858	81
Dry beans	27	48	29
Hay (alfalfa & sudan)	76	103	N/A
Rice	49	75	24
Safflower	19	64	55
Wheat	53	282	34
Almonds	363	292	71
Grapes (fresh, raisins, & processed)	278	120	N/A
Lemons	73	10	31
Oranges	142	32	25
Pistachios	24	17	27
Plums	43	13	32
Prunes	67	42	51
Walnuts	99	72	40
Broccoli	35	14	14
Cauliflower	31	11	20
Lettuce	52	13	8
Onions	47	15	38
Strawberries	46	2	11
Nursery products	124	—	N/A
Cattle & calves	53	—	3
Dairy products	63	—	2
Chicken & eggs	41	—	5
TOTALS	2,560	2,083	—

* Notes: The value is equivalent farm gate value. The acres figures assume average yields.

Definition of Crop Consumptive Use

The consumptive use of water by crops is synonymous with the term *evapotranspiration*. It is expressed as a volume of water per unit area, usually acre-feet per acre, and is a measure of the water transpired by plants, retained in plant tissue, and evaporated from adjacent soil surfaces over a specific period of time. ET varies throughout the year depending on solar radiation, humidity, temperature, wind, and stage of plant growth. For example, as a crop grows, ET increases until the crop reaches maximum cover. The evaporation component of ET is greatest when the plant is small and does not shade the soil surface. Further, the relationship between evaporation and transpiration is a dynamic one. When evaporation increases, transpiration decreases. ET is

Table 7-4. U.S. Department of Agriculture's Quantity Index of Agricultural Imports
(excludes fruits, nuts, and vegetables)

Index Values for:	1980	1985	1990	Percent Change 1980-1990
Total agricultural imports into U.S.	107	122	136	27.1
Competitive agricultural imports	100	118	123	23.0

Table 7-5. Agricultural Imports by Country of Origin
(in $ millions)

Country of Origin	1988	1990	Percent Change
Canada	2,256	2,927	29.7
Mexico	1,540	2,116	37.4
Australia	1,114	1,161	1.5
Brazil	925	1,016	9.8
New Zealand	749	786	4.9

the largest element in California's hydrologic budget, including the ET in forests, natural vegetation, agriculture, and landscaping.

The evapotranspiration of applied water is less than the total ET of a crop in most areas of the State because rainfall provides some of the crop requirements. This effective precipitation is subtracted from the total crop ET to determine the evapotranspiration of applied water (that portion of the crop ET provided by irrigation). Crop ETAW represents about 15 percent of the total evapotranspiration and associated evaporation in the State. Table 7-6 indicates the ETAW range of the major crop groups in the hydrologic regions of California.

Agricultural Water Use Efficiency. Agricultural water use efficiency has normally been defined as irrigation efficiency calculated by dividing the ETAW plus the leaching requirement by the applied water. Another measure of agricultural water use efficiency is the agricultural production per unit of water. Harvested yields per acre of most California crops have more than doubled during this century while irrigation methods have become more efficient. For example, one of California's major crops, on an acreage basis, is cotton. Figure 7-2 shows the increase in yields of lint per harvested

Table 7-6. Ranges of Unit Evapotranspiration of Applied Water
(acre-feet/acre per year)

Crop	NC	SF	CC	SC	SR	SJ	TL	NL	SL	CR
Grain	0.3-1.5	0.2-0.4	0.2-0.4	0.2-0.2	0.2-1.6	0.3-0.9	0.6-1.2	1.6-1.6	0.2-0.2	2.0-2.0
Rice	—	—	—	—	3.0-3.4	3.3-3.6	—	—	—	—
Cotton	—	—	—	—	—	2.3-2.5	2.5-2.5	—	—	3.3-3.2
Sugar beets	2.4-2.4	1.5-2.3	1.4-2.5	2.2-2.2	1.7-2.7	2.1-2.7	2.4-3.3	—	—	3.8-3.8
Corn	1.0-1.8	1.8-1.8	0.6-1.8	1.4-1.6	1.4-2.3	1.8-2.0	1.9-2.0	1.9-1.9	2.4-2.4	1.7-2.6
Other field	0.9-1.8	1.0-2.0	0.6-1.3	0.6-2.2	1.2-2.0	0.6-1.6	1.2-2.1	—	2.2-2.2	2.0-3.5
Alfalfa	1.5-2.8	1.5-2.7	1.9-3.0	2.7-2.7	1.8-3.2	2.4-3.3	2.9-3.3	2.3-2.5	3.8-5.0	4.3-6.6
Pasture	1.4-2.6	2.1-3.0	2.0-3.0	2.7-2.8	2.1-3.3	3.0-3.3	3.0-3.5	2.4-2.6	3.8-5.0	4.3-6.6
Tomatoes	—	1.9-2.1	1.0-2.0	1.8-2.3	1.6-2.1	1.6-2.2	2.0-2.3	—	—	2.9-2.9
Other truck	1.0-1.7	0.9-2.0	0.8-2.1	1.4-1.5	0.6-1.8	0.6-1.7	1.0-1.4	1.7-1.7	1.5-1.5	1.3-5.4
Almonds/pistachios	—	—	—	—	1.6-2.7	1.7-2.3	2.0-2.5	—	—	—
Other deciduous orchard	1.4-2.1	1.4-2.2	1.0-2.3	2.3-2.3	1.3-2.7	1.3-2.8	1.8-3.0	—	2.3-2.3	2.3-4.4
Subtropical orchard	—	—	1.0-2.0	1.7-1.8	1.3-2.0	1.0-2.1	1.7-2.2	—	2.6-2.6	3.8-4.4
Grapes	0.5-0.8	0.5-0.9	0.8-1.3	1.2-1.5	0.9-2.0	1.0-2.1	1.9-2.2	—	2.4-2.4	2.4-3.3

Note:
The North Coast Region encompasses numerous climate zones, reflected by a large range of ETAW values for certain crops.
The Subtropical category includes olives, citrus, avocados, and dates, which have varying water requirements. Ranges of ETAW for this category reflect the relative acreages of each crop within a region.
The cooler Delta climate reduces ETAW in some San Joaquin Region units for certain crops.
Some variation in values is caused by similar crops (or the same crop) grown at different times of the year.

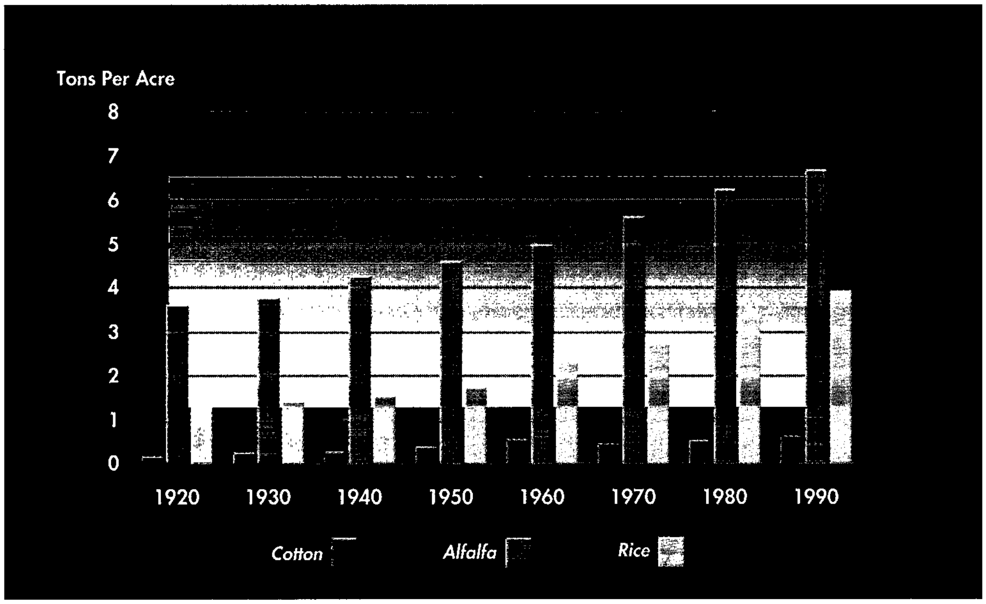

Figure 7-2. Yield of Cotton Lint, Rice, and Alfalfa per Acre 1920–1990

Official California Agricultural Statistic Service Data

acre for cotton since 1910. However, cotton is also valuable for the cotton seed as well as the lint. The historical increase in yields of alfalfa and rice are also displayed in Figure 7-2. In all cases, the production per acre-foot of ETAW has increased substantially. In fact, the ET of many crops has been reduced due to new varieties with shorter stature, shorter growing seasons, more disease resistance, and better ripening characteristics.

Historical Unit Water Use

To estimate agricultural water use, unit applied water and unit ETAW values in acre-feet for each crop acre are evaluated. The ranges of unit applied water values used for various regions of California are shown in Table 7-7. Agriculture's annual applied water decreased over 4 maf during the 1980s. This decrease was due to urbanization

Table 7-7. Ranges of Unit Applied Water for Agriculture by Hydrologic Region
(acre feet/acre per year)

Crop	NC	SF	CC	SC	SR	SJ	TL	NL	SL	CR
Grain	0.3-2.3	0.3-0.4	0.5-1.0	0.5-1.0	0.6-2.5	0.6-1.3	1.0-1.8	2.1-2.4	1.0-1.0	2.0-3.6
Rice	3.2-3.7	—	—	—	4.0-7.9	6.7-7.9	—	—	—	—
Cotton	—	—	—	—	—	3.1-3.3	3.0-3.3	—	—	4.1-5.5
Sugar beets	3.2-3.7	2.0-2.9	2.0-3.8	2.9-2.9	2.8-4.4	3.8-4.4	3.0-3.6	—	—	4.2-4.2
Corn	1.4-2.8	2.3-2.3	1.5-2.9	1.9-2.3	2.4-3.5	2.6-2.9	2.4-3.6	2.7-2.7	4.0-4.0	2.1-4.0
Other field	1.3-3.0	2.0-2.5	0.9-2.5	0.8-3.1	1.8-2.9	1.8-2.9	2.1-3.2	—	3.7-3.7	2.9-5.2
Alfalfa	2.0-3.5	2.6-3.3	2.6-4.0	4.2-4.5	2.6-4.9	3.8-4.9	3.7-4.8	3.2-3.4	5.5-8.0	6.8-9.4
Pasture	1.9-4.0	3.4-4.4	2.6-4.0	4.5-5.4	3.9-6.1	3.8-6.2	3.7-4.8	2.9-2.9	5.5-8.0	7.9-9.4
Tomatoes	—	2.4-2.4	1.7-3.3	3.0-3.0	2.6-3.5	2.7-3.5	3.1-3.4	—	—	4.3-6.4
Other truck	1.3-2.7	1.7-2.5	0.9-2.7	1.9-2.5	0.7-2.7	1.7-2.9	1.8-2.3	2.4-2.6	2.5-2.5	2.9-7.7
Almonds/pistachios	—	—	—	—	2.6-3.6	2.6-3.4	2.7-3.3	—	—	—
Other deciduous orchard	2.8-3.0	2.0-3.2	1.0-3.4	2.9-2.9	2.6-4.2	3.1-4.2	2.6-3.9	—	3.8-3.8	5.9-6.3
Subtropical orchard	—	—	1.0-2.5	2.1-2.3	2.4-2.9	2.4-2.5	1.7-2.2	—	3.5-3.5	4.2-5.9
Grapes	0.9-0.9	1.0-1.4	1.0-2.5	1.5-1.9	1.3-3.1	1.8-3.0	2.5-2.9	—	3.7-3.7	4.1-5.1

Note: Truck crops may reach higher annual unit applied water values when double or triple cropping occurs.

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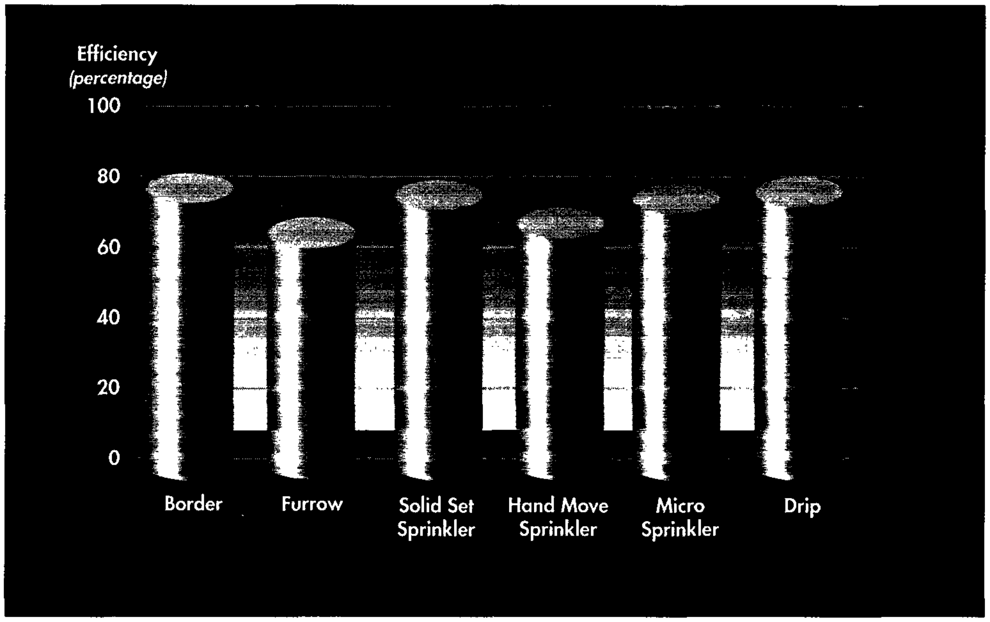
Figure 7-3. On-Farm Average Seasonal Application Efficiency of Various Irrigation Methods

Source: DWR/Local Agency Cooperative Mobile Irrigation Laboratory Program. The efficiencies were calculated from 1,000 field evaluations on less than 1 percent of California's farmland in San Diego, Riverside, Ventura, Kern, Kings, and Merced counties and cannot be considered a statewide average. Graded border and solid sprinkler efficiencies were high because of their use in mature orchards with shaded ground and protection from wind. Irrigation efficiencies are related to the distribution uniformity of a given irrigation method. The DU of border and furrow systems is determined by a different method than that used for sprinklers. Drip systems are evaluated by measuring their emission uniformity.



of irrigated land, changes in irrigation practices, and increased emphasis on water conservation since the 1976-77 drought and during the1987-92 drought.

Irrigation Management and Methods

One business decision the farmer must make is which irrigation method to use. To make any decision regarding an irrigation practice, detailed information is needed about soil properties, the system's capital costs, operation and maintenance costs, new management skills, the availability of water, the effect on water and energy use, and the effect on yields and quality. Most irrigation system improvements will only be made if such a change will increase the net returns of the farming operation.

In general, data indicate that on-farm irrigation efficiencies are higher than usually perceived by the general public. During the 1980s irrigation efficiencies rose about 10 percent, from an average of 60 percent to 70 percent. An analysis of data from the cooperative Mobile Lab Program is presented in Figure 7-3 indicating average irrigation efficiencies for various methods. Most data of this kind indicate that all methods of irrigation can be efficient if properly managed, and there is no superior method that will save a large percentage of water. No matter what method is used, the ET of the crop does not change substantially. Microirrigation does offer some reduction in evaporation when irrigating young trees and vines. Currently, there is a definite trend away from surface irrigation to pressurized systems for some crops. Drip and other forms of microirrigation are primarily being adopted for yield increases and other management benefits rather than solely to improve water application. The University of California, Davis, estimated the acreage irrigated by various methods recently. The results of the current survey are found in Table 7-8. A comparison with the earlier studies showed that surface-irrigated acreage has declined 13.3 percent since 1972, sprinkler-irrigated acreage has increased over five percent, and drip-irrigated acreage has increased from almost nothing to 8.7 percent at present.

The manner of water delivery to the farm from water purveyors also affects water use and irrigation efficiency. To manage irrigation water most effectively, a farmer should be able to turn water on and off at will, like a commercial enterprise in a city does. This is impractical with most agricultural water delivery systems due to the large volumes of water that must be conveyed. However, a number of agricultural water agencies are improving the water delivery flexibility to the farm. The increased flexibility is accomplished by allowing a farmer to give shorter notice to the district before receiving water and giving the farmer some allowance for adjusting flow rates and the duration of the irrigation.

Drainage and Salinity

A major consideration in water use is the salinity of the irrigation water, the salinity of the soil, and the physical characteristics of the soil that affect its internal drainage. For example, heavy soils in Imperial Valley, made up of shrink-swelling clay minerals with poor internal drainage, need tile drains in order to leach salts from the soil or crop production would not be feasible. Leaching requirements may represent 10 to 15 percent of the total applied water in this area.

Another area with a similar problem is the western side of the San Joaquin Valley. Inadequate drainage and accumulation of salts have been long-standing problems. As irrigated acreage increased, the problem became more widespread in the region where the soils are derived from marine sediments already high in salts and frequently high in trace elements. Percolation from continued irrigation has dissolved these compounds in many areas and moved them into shallow ground water aquifers where they concentrate due to poor subsurface drainage disposal. Other regions in California having soils with better drainage characteristics, and more rainfall to help leach the salts, normally do not have as severe drainage and salinity problems.

Water Price and Production Costs

Water price also affects agricultural water use, and at some point the retail cost can become too great for agricultural use. However, retail water prices are not as directly related to agricultural water use efficiency as is generally thought. Even though most farmers pay substantially less for water on a per acre-foot basis than their urban counterparts, their overall water costs for irrigation are a much higher percentage of their budget than that of the average home owner.

Table 7-8. Crop Acreage Irrigated by Various Methods
(percentages in 1991)

Crop	*Surface*	*Sprinkler*	*Drip*	*Subsurface*
Grain	88.8	10.8	0.0	0.4
Cotton	93.3	6.5	0.2	0.0
Sugar beets	86.7	13.3	0.0	0.0
Corn	99.1	0.0	0.0	0.9
Other field	89.5	9.3	0.7	0.5
Alfalfa	86.0	13.0	0.0	0.9
Pasture	81.8	12.0	0.0	6.2
Tomatoes	92.7	6.5	0.9	0.0
Other truck	55.1	29.5	15.4	0.0
Deciduous orchard	39.2	47.3	13.2	0.2
Subtropical orchard	11.5	80.6	7.9	0.0
Grapes	44.9	12.7	42.2	0.3
*Percentage of Acreage**	66.9	23.8	8.7	0.6

* Rice acreage not included

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Water Price and Agricultural Production

The effect of increases in the cost of irrigation water on crop production is a complex issue. Some schools of thought predict the impending water price effects of the 1992 Central Valley Project Improvement Act and the Reclamation Reform Act will encourage farmers to take substantial amounts of acreage out of production. Others say that the water price increases will cause those irrigating pasture or growing field crops to shift to higher-income crops. This discussion should reveal why neither prediction may be the case.

The decision by a farmer to bring a particular piece of land into production depends on a number of factors: the size of the capital investment needed (equipment, land, and land improvement costs); the farmer's skill, experience, and financial resources; the risk of crop or yield loss due to disease or drought; the expected income from crop sales; the likely variation in that income due to market price fluctuations; and the costs of production (including any hauling or processing costs paid by the farmer). The compliance requirements and income effects of government farm programs must also be considered. A primary factor, of course, is the availability of the resources needed to produce a particular crop: suitable soils and climate, labor, and water of sufficient quantity and quality.

Water price affects these factors both directly and indirectly; it affects the cost of production directly and the investment cost indirectly. The indirect link exists because the water cost affects the expected future net return from crop production on the land in question: the higher the water cost, the lower this return is expected to be. The market value of the land for crop production (aside from any speculative value for nonagricultural uses) is, in turn, based on the present worth of this expected net income.

Options may be available, however, to reduce the adverse impacts of a water price increase. Alternative water sources or water management practices may be available at a justifiable cost. Practices to reduce applied water in response to a price increase can be effective if the cost of their implementation is substantially less than the cost of the water they replace. (Such applied water reductions can also have "hidden" costs if they reduce deep percolation to a ground water basin that is used for a drought supply, for example.) Also, because of tradition, a present lack of appropriate skills and experience, or an unwillingness to accept risk or make a needed—but substantial—capital investment, a farmer may not be producing the crop that can provide the greatest net income.

The option to shift to another crop must be considered with respect to the farmer's financial resources, the suitability of climate and soils for the specific crop, and crop marketing conditions. (For many high-valued crops, the necessary market conditions include obtaining a contract with a food processor.) Because of such constraints, land planted to lower-valued crops like pasture or alfalfa may not be a sign of opportunity being ignored.

Even with a low-cost water supply, it is still in the farmer's economic interest to plant the crop that provides the greatest net income; a low-cost water supply just allows this crop to provide a greater net income than would otherwise be the case. However, in cases where alternative crops produce about the same gross income per acre but require much different quality and quantities of water, the different degree of impact on production cost can change the relative attractiveness of a crop in terms of net income.

If the impact of a substantial water price increase cannot be sufficiently moderated by any options available to the farmer, that farmer may not have the financial resources or economic incentive to continue farming, for any extended period, the land affected by the water price increase. In this case, the land will be placed on the market, either voluntarily or involuntarily, and its price reduced, reflecting the water price increase. Under these conditions, the final effect is likely to be a change in the financial status of the person who owns the land and perhaps also the person who farms the land rather than the type of crop grown.

Water Price and Agricultural Production (continued)

Price increases due to intermittent surface water shortages, when farmers have to use more costly ground water, for example, can be "absorbed" more or less successfully by farmers with sufficient financial resources to weather short-term reductions in net income. When these shortages become more frequent or where the unavailable surface water has a high fixed cost attached, the necessary financial resources to absorb even short-term water price increases are less likely to be available.

The prices received for different crops, the viability of the irrigated acres, the availability of alternative sources of water, the net income resulting from a specific crop or mix of crops, and the options and financial resources available to the farmer all affect whether or not a certain crop is produced. It is extremely difficult to predict the specific effects of a water price increase on agricultural production. In general, however, an increase in the price of water will probably cause the value of the farm land to drop, and land only marginally productive, farmed by those with very limited financial resources, will be unable to continue production. The mix of crops on the land remaining in production may not be substantially affected.

However, expanding markets for high-income crops will probably increase the demand for land that is currently economically uncompetitive for producing these types of crops. Although rising water prices will tend to lower production, increased demand for high income crops should more than offset this effect.

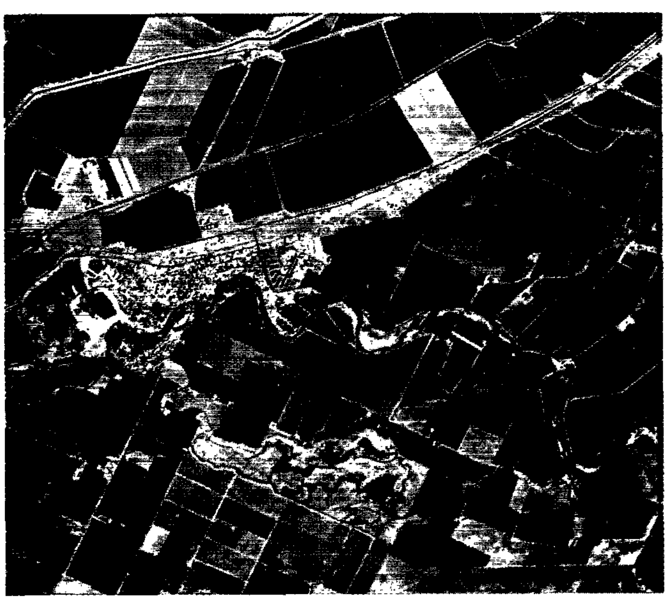
Cropping Patterns in California

Over 250 different crops are grown in California due to the State's fertile soils, long growing season, and multitude of microclimates. Which crops are grown is the result of farmers' business decisions. Farmers must take into account the suitability of land and climate for various crops, market conditions, production costs, the available infrastructure, their own abilities, and what risks they are willing to take.

Historic Agricultural Acreage

Agricultural water use is estimated by determining what crops are grown and where. Figure 7-4 shows the increase in irrigated agricultural acreage since the late 1800s, although certain field crops and irrigated pasture have decreased in recent years.

Since 1950, DWR has surveyed agricultural land use. Since 1967, intensively cropped counties have been mapped about every seven years to assess the locations and amounts of irrigated crops. The acreages of crops grown each year are also estimated using the annual crop reports produced by county Agricultural Commissioners and the California Department of Food and Agriculture Livestock and Crop Reporting



High-altitude photography reveals cropping patterns that are mapped, digitized, and stored in data banks. The red patterns shown here are irrigated crops grown in the region.

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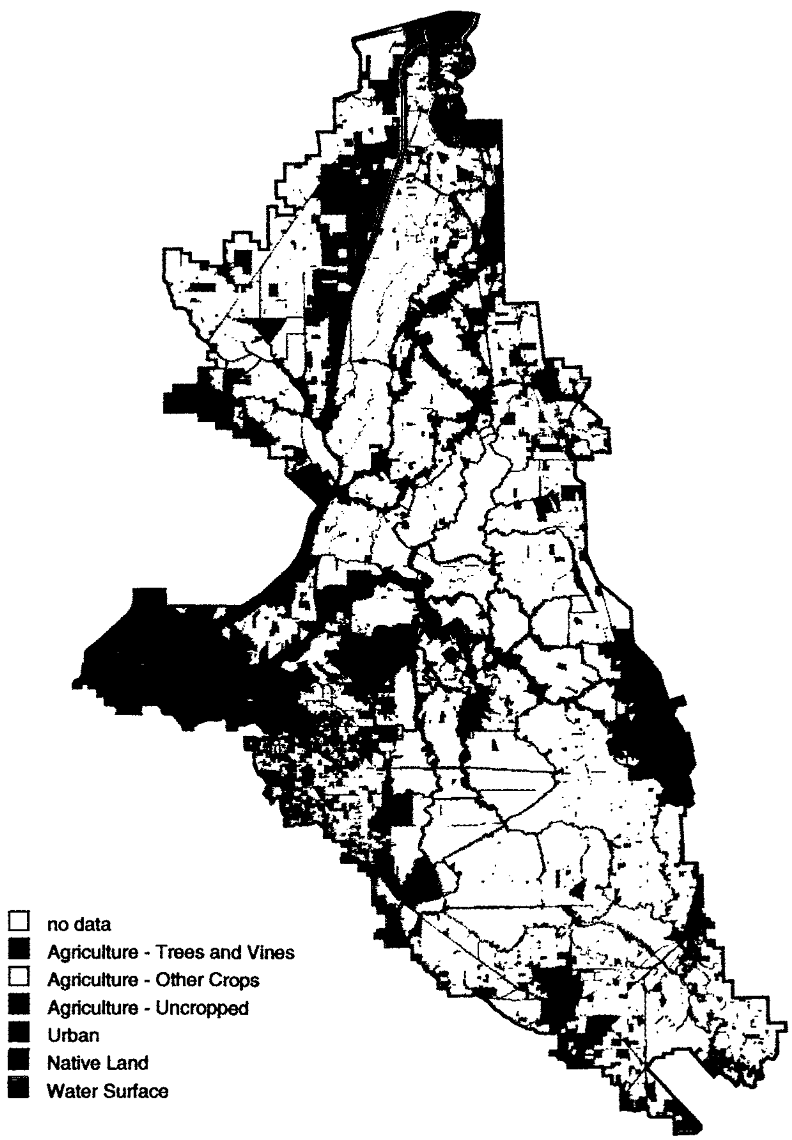
Land Use Survey Program

Since 1950, DWR has conducted detailed land use surveys as part of its Land Resource and Use Program. Every major water-using county is resurveyed about every seven years. The surveys use low- and high-elevation aerial photography to determine land use and boundaries, and the information is mapped on U.S. Geological Survey $7^1/_2$-minute quadrangle maps, scale 1:24,000 acres. The surveys are then used in analyses of urban and agricultural water needs.

During each survey, the maps are taken to the field to make positive land use identification and to verify those interpreted from the photographs. In addition, crop acreage information from county agricultural commissioners and farm advisors is used to help determine the extent of double cropping. The acreage of each crop type (and other land uses) are determined and summarized by quad, county, irrigation district, and hydrologic area. The present method used to generate the maps and process the resulting data is computer digitizing of land use boundaries and subsequent data analysis using a geographic information system. Below is a map of the Sacramento-San Joaquin River Delta resulting from the 1991 in-depth survey and updated using information from DWR's 1993 reconnaissance survey.



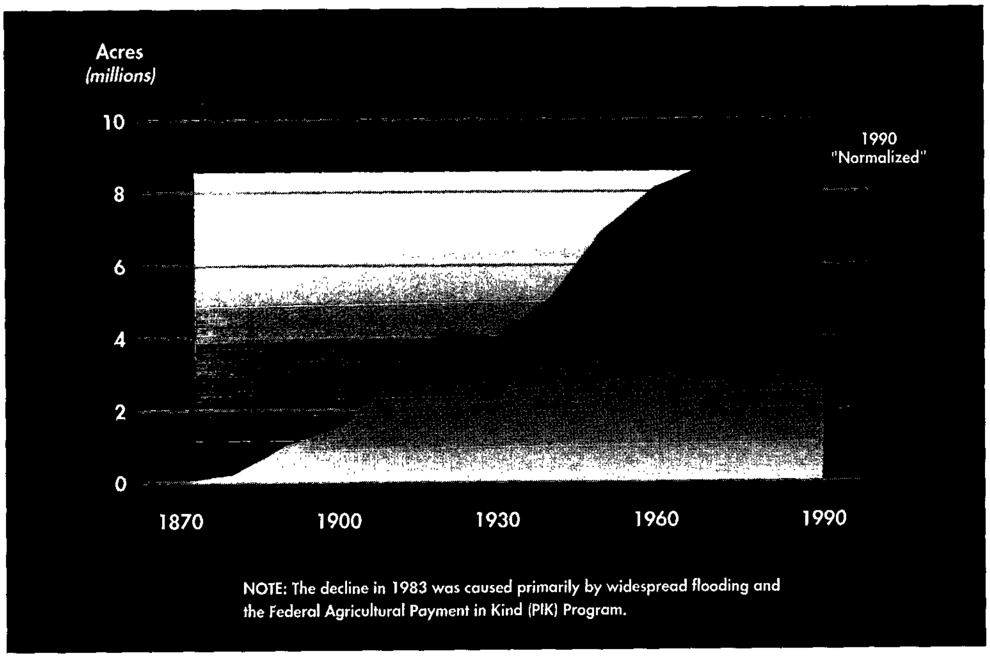


Figure 7-4. Irrigated Acreage in California 1870-1990

Service. Between 1980 and 1989, there was a five percent decrease in cropped acreage; however, this decade was also a period of fluctuating acreage when government programs, agricultural markets, and climate (floods and droughts) significantly affected crop plantings. Irrigated agricultural acreage reached its peak in 1981, with 9.7 million acres, dropped 900,000 acres in 1983 due, in large part, to the Payment-in-Kind Program, but then rose again by 800,000 acres in 1984. During the latter part of the 1987-92 drought, lands were fallowed due to shortages in surface water supplies. Therefore, data from the 1980s did not show reductions or increases in irrigated acreage that could be used to forecast future water service needs.

Water Supply and Water Price

The historic increase in irrigated acreage, and the wide variety of crops grown, are the result of the water supply system developed by agriculture at the local level or with the support of the State and federal government.

During normal years, a large amount of agricultural water comes from ground water supplies and is pumped mostly by individual farmers and ranchers. However, the majority of agricultural water supplies are obtained from water districts, which obtain most of their supplies from surface water, with a lesser portion from ground water sources. A small percentage of agricultural water is diverted directly from streams and rivers by the individual farmers and ranchers.

In 1991, at least 78 agencies each provided over 50,000 af to their service areas. As with urban agencies, a number of factors influence these agencies' water prices, including water sources, transportation, pricing policies, agency size, and weather.

Agricultural Retail Water Prices

About 70 to 80 percent of agricultural water districts' revenues typically come from water charges during a normal water year. The remainder of their water revenues are derived from property taxes. Many water districts (especially in the Sacramento Valley) charge on the basis of acres irrigated and at different per-acre rates, depending upon the types of crops that are grown. Generally, all the prices for individual crops are

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Table 7-9. Typical Agricultural Retail Water Costs in 1991 by Hydrologic Region
(weighted average)

Hydrologic Region	*Number of Districts Responding to Survey*	*District Water Sources*	*Weighted Average Cost ($/acre-foot)*
North Coast	2	Other*	3
San Francisco Bay			44†
Central Coast	1	CVP, Other	14
South Coast	6	SWP, Colorado River, MWDSC, Other	252
Sacramento River	14	CVP, SWP, Other	12
San Joaquin	10	CVP, Other	19
Tulare Lake	11	CVP, SWP, Other	86
North Lahontan	2	Other	7
South Lahontan	1	SWP, Other	150
Colorado River	3		12

Costs are estimated at the farm headgate and exclude farmers' costs to distribute water to their fields.
* Local surface or ground water supplies.
† Source: Santa Clara Valley Water District

calculated on a water duty (the amount of water required to irrigate a given area for cultivation of some crop).

In late 1991 and early 1992, the Department of Water Resources mailed water cost surveys to selected water districts that serve farms in California. Almost all of the responses were from medium- or large-sized agricultural water purveyors. There were 33 responses from the Central Valley.

Table 7-9 summarizes 1991 agricultural retail rates by hydrologic region. The most expensive agricultural water sold by districts is found in the South Lahontan, South Coast, and Tulare Lake regions. The least expensive irrigation water is found in the North Coast, northeast California (North Lahontan), Colorado Desert, and the Sacramento Valley. As with urban water prices, a major element is the transportation cost of moving water from the area of origin to the area of use. Transportation costs include the capital, operation, and maintenance costs of facilities (such as aqueducts, pipelines, and pumping plants) plus the energy cost of moving the water. In addition, conveyance losses are usually incurred, which increases the cost of water delivered to the final users. Because of the recent prolonged and severe drought, many of these 1991 water costs may be higher than what would have been expected for a non-drought year.

Agricultural Ground Water Production Costs

As with urban areas, agricultural ground water costs vary considerably throughout California. Many factors influence these costs, including depth to ground water, pump efficiencies, and electricity rates. Another factor was the drought which lowered ground water levels and increased pumping costs. Table 7-10 presents a range of averages for agricultural ground water costs for the hydrologic regions. The costs include capital, operation (including pumping energy costs), maintenance, and replacement costs. Costs were determined from a survey of well drillers in the hydrologic regions and from DWR district files.

Agricultural Water Conservation

Agricultural water conservation has taken a different path from that of the urban sector. Historically, irrigated agriculture has had the University of California, California State Universities, local Resource Conservation Districts, and U.S. Department of Agriculture programs to provide technical management assistance over many decades. These efforts have often included improved and better crop varieties, high-yielding food and fiber crops, disease-resistant crops, frost-resistant crops, and irrigation and farming methods that help preserve soil structure and fertility, as well as maintaining favorable soil salinity and long-term productivity. These collective efforts have resulted in constant improvement in use of resources for agricultural production and significant increases in yield per-acre for almost all crops grown in California. Irrigation efficiencies have been increased and applied water requirements reduced over time as a result of these efforts.

Even though irrigation management continued to improve in the 1970s and 1980s, using the existing technical assistance programs mentioned above, agricultural water agencies now fill an active role paralleling that of urban water agencies in conservation efforts. Two pieces of legislation that accelerated this effort are the California Agricultural Water Management Planning Act of 1986 (AB 1658) and the federal Reclamation Reform Act of 1982.

AB 1658 required all agricultural water suppliers delivering over 50,000 acre-feet of water per year to prepare an Information Report and identify whether the district has a significant opportunity to conserve water or reduce the quantity of saline or toxic drainage water through improved irrigation water management. The legislation affected the 80 largest agricultural water purveyors in California. The districts that have a significant opportunity to conserve water or reduce drainage are required to prepare Water Management Plans.

The Reclamation Reform Act of 1982 required federal water contractors to prepare Water Conservation Plans. In California, the U.S. Bureau of Reclamation's Mid-Pacific Region developed a set of *Guidelines to Prepare Water Conservation Plans* and required all federal water contractors serving over 2,000 acres to submit water conservation plans. In 1990, USBR requested assistance from DWR to upgrade the guidelines on how to prepare water conservation plans. New guidelines for USBR's

Table 7-10. Typical Agricultural Ground Water Production Costs in 1992 by Hydrologic Region

Region	*Ground Water Costs ($/acre-foot)*†
North Coast	10-70
San Francisco Bay	60-130
Central Coast	80
South Coast	80-120
Sacramento River	30-60
San Joaquin	30-40
Tulare Lake	40-80
North Lahontan	60
South Lahontan	20
Colorado River	90

† The range represents the average cost at specific locations within a region, and includes capital, operation, maintenance, and replacement costs.

Mid-Pacific Region were prepared and DWR is providing assistance to USBR contractors to develop, update, and implement water conservation plans. The Central Valley Project Improvement Act of 1992 required the USBR's Mid-Pacific Region to revise its existing guidelines for reviewing conservation plans to include, but not be limited to, BMPs and Efficient Water Management Practices developed in California. The 1992 Strategic Plan for the USBR has identified water conservation as a key element for improving the use and management of the nation's water resources.

Enactment of AB 3616 in 1990 charged DWR to establish an Advisory Committee consisting of members of the agricultural community, University of California, California Department of Food and Agriculture, environmental and public interest groups, and other interested parties to develop a list of Efficient Water Management Practices for agricultural water supplies. Approximately 29 practices are under consideration.

The AB 3616 advisory committee is working to develop a process for agricultural water management plans for implementation of EWMPs within the framework of rights and duties imposed by existing law. Water management plans will identify water conservation opportunities and set a schedule for implementation. It is difficult to assess the specific benefits of EWMPs at the present time. Calculation of water savings resulting from EWMP implementation will require a detailed planning process by each individual district, including analysis of technical feasibility, social and district economic criteria, and legal feasibility of each practice. The University of California at Davis surveyed 23 of the 79 agricultural water agencies affected by AB 1658 to assess what practices similar to EWMPs are currently in place. The results of that survey are also displayed as percentages in Table 7-11. It is expected that the AB 3616 process will replace that contained in AB 1658. Currently, the advisory committee has drafted a Memorandum of Understanding that will commit signatories to the development of water management plans.

DWR continues to cooperate with many local agencies to implement measures that are potentially included on the list of EWMPs. These include providing real-time irrigation scheduling data through the California Irrigation Management Information System; providing on-farm irrigation system evaluations through the Mobile Irrigation Management Laboratory (Mobile Lab) program; offering advice on redesigning fee structures; and offering loans for installation of water measurement devices and construction of regulatory reservoirs. A cooperative effort, along with Pacific Gas and Electric and others, has helped develop the Irrigation Training and Research Center at California Polytechnic State University, in San Luis Obispo.

As mentioned in the urban water use section, the definition of water conservation recognizes that reducing applied water results in additional water supply only when the water would otherwise be lost to evapotranspiration or a saline water body such as the Pacific Ocean. In the agricultural sector, this condition applies to a few specific areas, primarily the Colorado River Region, which drains to the Salton Sea, and the west side of the San Joaquin Valley. In the Sacramento River and the San Joaquin River basins, excess applied irrigation water is either reused, ultimately percolates to ground water, or drains back into rivers that flow to the Delta. Reducing applied water in these basins reduces return flows, which must be made up by increasing reservoir releases to maintain specified outflows through the Delta.

Drainage Reduction

A major effort has been the cooperative demonstration projects of new and emerging technologies for on-farm irrigation management to reduce applied water, hence drainage and deep percolation, in drainage problem areas. The west side of the

Table 7-11. Summary of Current Efficient Water Management Practices

Practice	*Currently in Place** *(percentage)*
Irrigation Management	
1. Improve water measurement and accounting	70
2. Conduct irrigation efficiency studies	43
3. Provide farmers with "normal-year" and "real time" irrigation, scheduling, and crop evapotranspiration ET information	52
4. Monitor surface water qualities and quantities	52 & 100 respectively
5. Monitor soil moisture	13
6. Promote efficient pre-irrigation techniques	17
7. Monitor soil salinity	26
8. Provide on-farm irrigation system evaluations	35
9. Monitor quantity and quality of drainage waters	39 & 52 respectively
10. Monitor ground water elevations and qualities	83 & 43 respectively
11. Evaluate and improve water user pump efficiencies	39
12. Designate a water conservation coordinator	48
Physical Improvement	
13. Improve the condition and type of flow measuring devices	61
14. Automate canal structures	35
15. Line or pipe ditches and canals	22
16. Modify distribution facilities to increase the flexibility of water deliveries	43
17. Construct or line regulatory reservoirs	26
18. Construct District tailwater reuse systems	39
19. Develop recharge basins for systems	35
20. Improve on-farm irrigation and drainage systems	43
21. Evaluate efficiencies of District pumps	57
22. Provide educational seminars	57
Institutional Adjustments	
23. Improve communication and cooperative work among district, farmers, and other agencies	65
24. Change the water fee structure in order to provide incentives for more efficient use of water and drainage reduction	43
25. Increase flexibility in water ordering and delivery	65
26. Conduct public information programs	48
27. Facilitate financing capital improvements for District and on-farm irrigation systems	43
28. Increase conjunctive use of ground water and surface water	22
29. Facilitate, where appropriate, alternative land uses	4

* Based on a 1992 U.C. Davis survey of 23 agricultural water suppliers delivering over 50,000 AF of irrigation water.

San Joaquin Valley contains hundreds of thousands of acres underlain by poorly drained soils and shallow ground water. Continued irrigation requires the removal of shallow ground water to prevent water logging and salinization of soils which damage crops and reduce yields. In addition, some of the drain water contains toxic elements in sufficient quantities to impact waterfowl habitat.

Since the 1950s, three major State and federal interagency studies have been conducted regarding agricultural drainage disposal. Before 1983, study recommendations revolved around the construction of a drainage canal (San Joaquin Valley Drain) to transport drainage water to the ocean through the Sacramento-San Joaquin Delta.

The federal CVP constructed part of the San Luis Drain, the first phase of the San Joaquin Valley Drain, to serve the drainage needs of the CVP's San Luis Unit. The drain terminated in Kesterson Reservoir, an interim storage and evaporation reservoir in Merced County. In 1983, deformities and deaths of aquatic birds at Kesterson Reservoir were observed and determined to be caused by selenium toxicity. The presence of high concentrations of selenium in drainage water significantly changed the strategy for resolving drainage problems in the San Joaquin Valley.

San Joaquin Valley Drainage Program

In 1984, the San Joaquin Valley Drainage Program was established as a joint federal and State effort to investigate drainage and drainage-related problems in light of the new conditions. The SJVDP published its recommended plan in September 1990. The study and resulting plan focused on in-valley management of drainage and drainage-related problems. The recommended plan should guide management of the agricultural drainage problem for several decades into the future. In December 1991, eight State and federal agencies signed a Memorandum of Understanding to coordinate activities implementing the plan. A strategy was also developed to serve the following purposes: (1) establish a continuing coordination structure; (2) define and prioritize implementation needs; (3) identify federal, State, local, and private roles in implementation; (4) recommend implementation actions; and (5) seek agreement of involved parties.

The implementation strategy also includes developing a long-term monitoring program for tracking drainage conditions, determining the impacts of actions to manage drainage problems, and formulating a plan for long-term management of drainage data base programs. This bulletin assumes the land retirement and source control (conservation) elements of the recommended plan will be implemented; the elements are discussed in the next section.

Another consideration in projecting a slight reduction of agricultural acreage by 2020 was the retirement of lands with drainage and selenium concentrations, as recommended by the San Joaquin Valley Drainage Program in *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, September 1990. That report identified the need for 75,000 acres of land retirement by 2040. Assuming that land retirement will occur uniformly over time, about 45,000 acres of land retirement could occur by 2020.

The importance of a solution to drainage problems on the west side of the San Joaquin Valley cannot be overstated. Without adequate drainage management, soil salinization will occur and potentially cause almost 500,000 acres of land to be abandoned by 2040, according to the SJVDP report.

Irrigation Efficiency

Another consideration of agricultural water use projections is irrigation efficiency, which as previously stated is the ETAW of farm fields divided by the applied water. Previously, DWR has assumed that irrigation efficiencies could improve to between 70 and 75 percent. Recently, an agricultural sub-work group on the Bay-Delta Proceedings formalized an average target on-farm efficiency for the San Joaquin Valley; the average was computed to take into account the need for leaching of salts. An efficiency of 73 percent was considered appropriate for the San Joaquin Valley using the following formula:

$$\mathrm{SAE} = \frac{\mathrm{ETAW} + \mathrm{LR}}{\mathrm{AW}}$$

where SAE is seasonal application efficiency; ETAW is the evapotranspiration minus effective precipitation; LR is leaching requirement; and AW is applied water. The limiting factor leading to the 73 percent target irrigation efficiencies was the assumption that a distribution uniformity of 80 percent was the maximum attainable in the field. This target assumes that full production is achievable and yields will not be reduced. For this report it is assumed that 73 percent is a reasonable average target on-farm irrigation efficiency for agriculture in all regions of the State by 2020. Some areas of the State, such as Westlands Water District, Kern County Water Agency, and Imperial Irrigation District have on-farm irrigation efficiencies ranging from 75 percent to over 80 percent. Overall district efficiencies of irrigation water suppliers sometimes exceed 95 percent.

When this target efficiency was used for an analysis of the water conservation potential in the San Joaquin Valley, only an additional 14,000 af were determined to be conservable. A number of other studies have indicated up to 290,000 af of conservable water in the Central Valley (Central Valley Water Use Committee, 1987). In both cases the analysis was criticized because of the lack of good on-farm applied water data in many areas. The CVWUC report was one of the few that provided a range of uncertainty of plus or minus 100,000 af. Most experts agree that a precise number would be difficult to attain. In any case, the estimates of the remaining agricultural water conservation potential are extremely small compared to the total amount of water applied in agriculture for two reasons. The most important is that improvements in irrigation efficiency do not necessarily result in reductions in depletions in most hydrologic areas, other than the two exceptions mentioned previously. Secondly, only nominal improvements in irrigation efficiency are still practicable.

The source control (conservation) element of the preferred plan of the San Joaquin Valley Drainage Program was considered to be implemented for the purposes of this bulletin. As the SJVDP report mentioned, many practices were already occurring. Adopting the source control element results in 113,000 af of applied water reduction.

Agricultural Water Demand Forecast

1990 Level of Development

Bulletin 160 forecasts of agricultural acreage begin with a determination of a base-year level of development, 1990. This base acreage normally differs from the actual acreage irrigated in the base year. This is particularly evident in this bulletin because the base year of 1990 was a drought year.

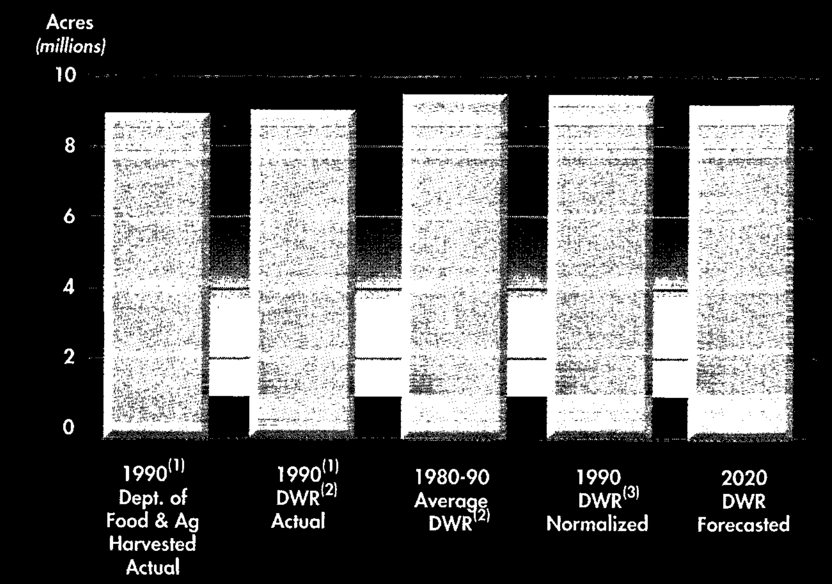
Agricultural acreage data for the 1980s were developed from DWR land use surveys and crop statistics developed by the Department of Food and Agriculture. Actual acreage values for 1990 were adjusted, based on averages of the 1980s, to reflect average year water supply and normal market conditions; the resulting base-year values are termed *1990 normalized*. The normalized acreage is shown in Figure 7-5, and Table 7-12 shows irrigated acreage by hydrologic region.

Agricultural Acreage Forecast

This California Water Plan Update relies on integrating three forecasting methods to estimate future agricultural acreage by crop type. The methods are: (1) expert opinion of land use trends and land capabilities, population projections, and local planning information obtained by DWR Land and Water Use Analysts; (2) DWR's Crop Market Outlook; and (3) DWR's Central Valley Production Model.

The CMO is based on the collective opinions of bankers, farm advisors, commodity marketing specialists, and others. The CMO is grounded on three primary factors:

Figure 7-5. Various Estimates of Irrigated Crop Acreage in California



1 Total acreage is drought impacted.
2 Based on gross acreage from DWR land use surveys minus roads, farmsteads, etc.
3 Based on the 1980-90 average acreage is normalized to remove the effects of drought and short-term market fluctuations.

(1) the current and future demand for food and fiber by the world's consumers; (2) the shares of the national and international markets for agricultural production that are met by California's farmers and livestock producers; and 3) technical factors, such as crop yields, pasture carrying capacities, and livestock feed conversion ratios.

The CMO assumes there is no direct relationship between food consumed by Californians and food grown in California. For instance, all corn silage and hay in California are used by livestock. Most cotton is exported. California provides more than 80 percent of the nation's processing tomatoes, tree nuts, lemons, olives, prunes, and grapes.

Much of the bulk foodstuffs and fiber consumed in California is grown outside the State. This dependence will broaden in the future as population grows. For instance, California is the number-seven cattle-producing state, but feed grains fed to California livestock are supplemented by feed from out of state. In short, modern transportation systems and food storage technology combine with trade and a market economy to allow California to benefit greatly from specialization in agricultural production.

The ability of California's farmers to help meet the world's future demands for food and fiber will be determined by various supply side- and demand-side factors. These factors include:

- water quality regulation
- urban encroachment
- future crop yields
- access to world markets
- government farm programs
- regulation of farm chemicals and the availability of affordable alternatives

- the availability of an affordable water supply
- emergence of agricultural export capability in other countries
- labor and labor overhead
- species protection

The comparative advantages for farmers will increase or decrease as the costs per unit of output change for farmers in California and competing regions, and as trade barriers and tariffs change. These will, in turn, affect our shares of domestic and international markets. Among other cost components that affect farm production costs and sales prices are energy, labor, labor overhead, and pest control.

California produces more than half of our nation's fresh and processed vegetables. A significant amount of our vegetable crops are exported, but some growers of certain vegetables face increasing competition from imports. All vegetables are irrigated and many are double-cropped. California vegetable acres have increased substantially in the past 20 years due to increasing comparative advantages in production and rising per capita consumption. Some observers expect this trend to continue at a faster rate than any other crop group. Figure 7-6 reflects this trend.

High value tree fruit, nut, and vine acreage has expanded significantly in California over the last 20 years. California now dominates the U.S. market for most of the major crops in this category, often with over 80 percent of U.S. production. Exports for many of these crops are also important. Most fruit, nut, and vine acres are irrigated. Most of these perennial crops are grown for both the fresh market and the processing market.

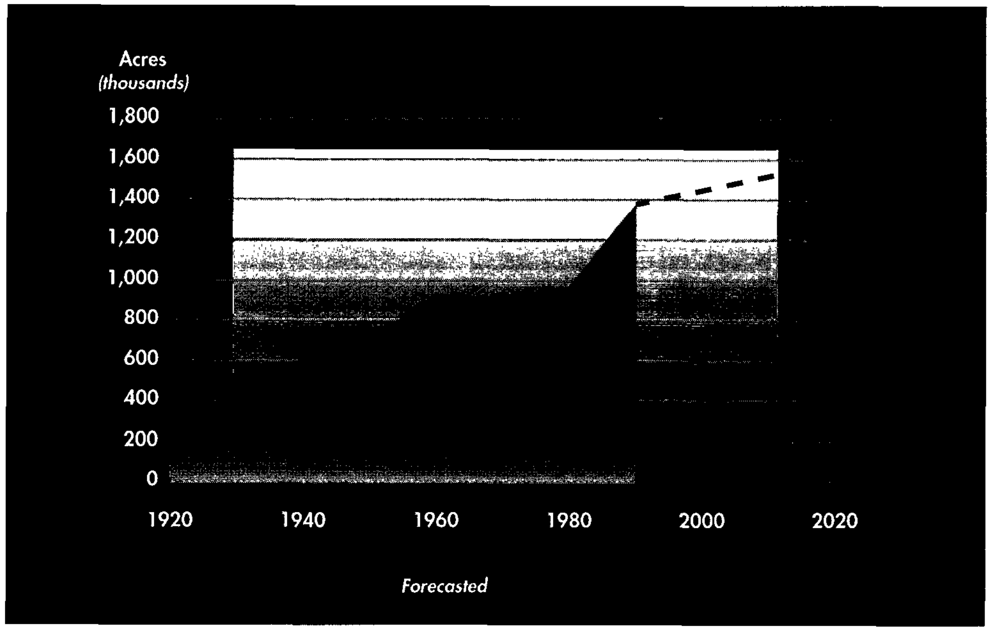
The CVPM is a programming model of farm production activities in 40 areas covering California's Central Valley. It incorporates detailed information on production practices and costs as well as water availability and cost by source for each area.

Table 7-12. California Crop and Irrigated Acreage by Hydrologic Region 1990
(normalized, in thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*Total*
Grain	82	2	28	11	303	182	297	6	1	76	988
Rice	0	0	0	0	494	21	1	1	0	0	517
Cotton	0	0	0	0	0	178	1,029	0	0	37	1,244
Sugar beets	2	0	5	0	75	64	35	0	0	35	216
Corn	1	1	3	5	104	181	100	0	0	8	403
Other field	3	1	16	4	155	121	135	0	1	55	491
Alfalfa	53	0	27	10	141	226	345	43	34	256	1,135
Pasture	121	5	20	20	357	228	44	110	19	32	956
Tomatoes	0	0	14	9	120	89	107	0	0	13	352
Other truck	21	10	321	87	55	133	204	1	2	187	1,021
Almonds/pistachios	0	0	0	0	101	245	164	0	0	0	510
Other deciduous	7	6	20	3	205	147	177	0	4	1	570
Citrus/olives	0	0	18	164	18	9	181	0	0	29	419
Grapes	36	36	56	6	17	184	393	0	0	20	748
TOTAL Crop Area(1)	326	61	528	319	2,145	2,008	3,212	161	61	749	9,570
Double Crop	0	0	98	30	44	53	65	0	0	102	392
Irrigated Land Area	326	61	430	289	2,101	1,955	3,147	161	61	647	9,178

(1) Total crop area is the land area plus the amount of land double cropped.

Figure 7-6. Irrigated Vegetable Acreage in California 1920–1990



Information on the relationship between the production levels of individual crops and crop market prices is also an important part of the model. The purpose of the CVPM is to evaluate the influence of production costs, resource availability, and market demand on the future economic viability of different crops in various areas of the Central Valley.

The CVPM and a review of crop acreage trends by DWR experts were used in conjunction with the CMO forecasts to determine overall crop acreage projections to 2020. All forecasting methods indicate a continuing decline in irrigated pasture as is illustrated in Figure 7-7. Agricultural acreage and applied water are expected to decrease

Figure 7-7. Irrigated Pasture Acreage in California 1950–2020

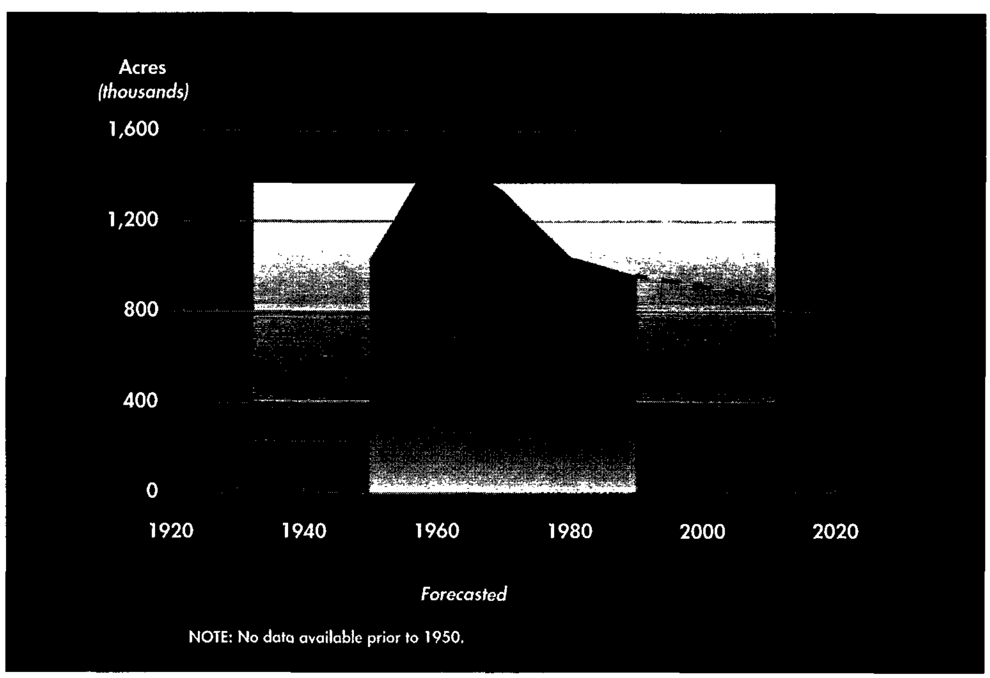


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Table 7-13. California Crop and Irrigated Acreage by Hydrologic Region 2020 (Forecasted)
(thousands of acres)

Irrigated Crop	NC	SF	CC	SC	SR	SJ	TL	NL	SL	CR	Total
Grain	72	2	23	1	295	179	258	9	0	70	909
Rice	0	0	0	0	482	15	0	1	0	0	498
Cotton	0	0	0	0	0	178	949	0	0	67	1,194
Sugar beets	10	0	5	0	72	45	25	0	0	40	197
Corn	1	0	6	2	115	183	98	1	0	3	409
Other field	3	1	15	0	158	122	130	0	0	26	455
Alfalfa	65	0	24	6	152	156	240	52	26	226	947
Pasture	122	4	15	6	320	171	22	104	19	30	813
Tomatoes	0	0	15	4	132	88	85	0	0	14	339
Other truck	28	11	347	43	65	201	350	2	1	203	1,250
Almonds/pistachios	0	0	0	0	125	263	173	0	0	0	561
Other deciduous	7	6	19	3	217	151	178	0	2	2	585
Citrus/olives	0	0	16	116	29	11	190	0	0	30	392
Vineyard	38	40	81	3	24	189	363	0	0	15	753
TOTAL Crop Area	346	64	566	184	2,186	1,952	3,061	169	48	726	9,302
Double Crop	0	0	137	12	72	68	90	0	0	123	502
Irrigated Land Area	346	64	429	172	2,114	1,884	2,971	169	48	603	8,800

over the next 30 years. Figures 7-8 and Table 7-13 indicate the projected acreage for crops in the major hydrologic regions of the State for the year 2020.

This forecast is generally optimistic about the ability of California farmers to compete in a world with fewer trade restrictions, smaller federal crop programs, and increasing crop production capacity worldwide. The outlook is particularly optimistic for California's high-value crops.

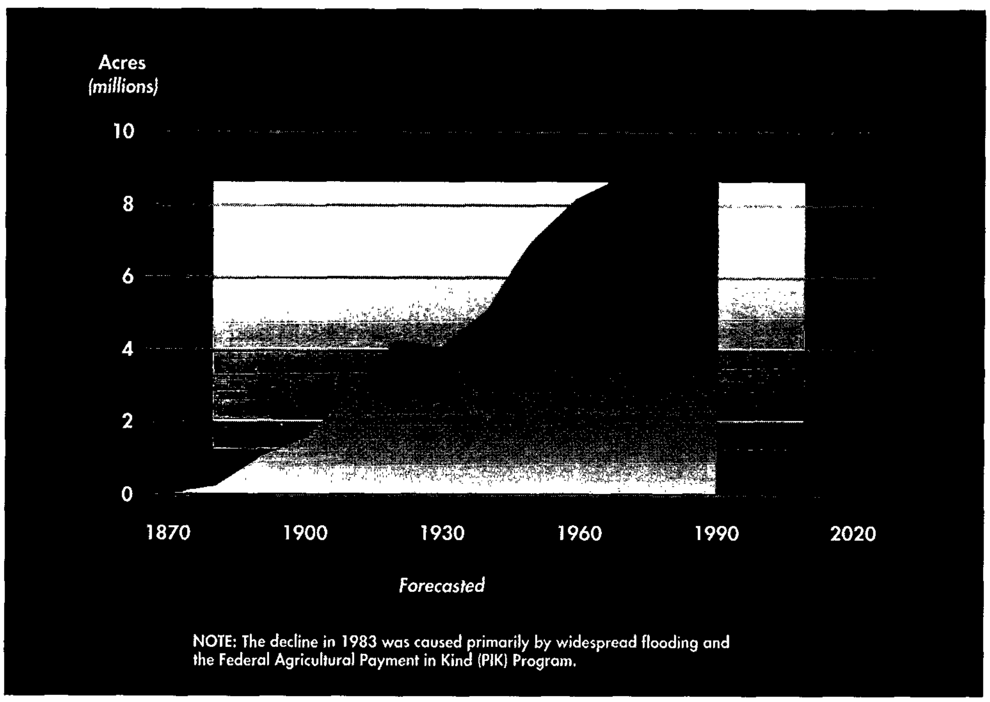

Figure 7-8. Irrigated Acreage in California 1870–2020

Note: The decline in 1983 was caused primarily by wet conditions and the federal agricultural payment in kind (PIK) program. The decline in 1987-90 was due to drought.

Table 7-14. Annual Agricultural Applied Water Reductions and Related Reduction Depletions by Hydrologic Region 2020 (forecasted)
(thousands of acre-feet)

Region	*Applied Water Changes* 1990-2020*	*Depletion Changes Due to Acreage Reductions or Crop Shifts*	*Depletion Changes from Irrigation Efficiency Improvement (Level I Programs)*
North Coast	68	45	0
San Francisco Bay	2	2	0
Central Coast	49	27	0
South Coast	−345	−278	−10
Sacramento River	−290	−40	0
San Joaquin River	−633	−316	−20
Tulare Lake	−780	−464	−90
North Lahontan	14	21	0
South Lahontan	−64	−49	−10
Colorado River	−342	−58	−200
Net Change	−2,321	−1,070	−330

*Applied water changes result from acreage reductions, crop shifts, and irrigation efficiency improvement.

Urbanization of Agricultural Lands

A primary consideration in projections of decreased agricultural acreage was the continued development of irrigated agricultural lands for urban use. In most cases, the conversion of agricultural lands to urban uses does not reduce water demands. Often prime agricultural lands are also prime lands for urban development as cities surrounded by agriculture continue to grow. Currently, agriculture moves onto less desirable lands as urban acreage expands. This trend could affect the trend of increased production per unit of water as illustrated earlier in this chapter.

The California Department of Conservation has estimated the conversion of prime farmlands to urban uses since 1984. Farmlands must be irrigated to be considered prime in California. Conservation's most recent report identifies nearly 32,000 acres of prime land converted to urban use since 1984. In this bulletin the primary agricultural areas impacted by such conversions are in the South Coast Region and in the Central Valley from Sutter County southward.

2020 Agricultural Water Demands

The applied water used by agriculture decreased by over 4 maf between 1980 and 1990. This was due to a reduction in acreage, a change in cropping patterns, and an average improvement in irrigation efficiency from 60 percent to 70 percent. The reductions in applied water of 2.3 maf by 2020 are due to a smaller increase in irrigation efficiency to 73 percent by the adoption of EWMPs, but are dominated by reduced agricultural acreage and shifts in cropping patterns.

The areas where reductions in applied water result in reductions in depletions are the drainage problem areas on the west side of the San Joaquin Valley and in the Imperial Valley. Reductions in applied water may be beneficial in certain cases (for example, pesticide movement) and detrimental in others (for example, wildlife habitat). Such analyses and decisions need to be made at the local level through local water management plans. The positive or negative effects of site-specific reduction in applied water have not been evaluated in this bulletin. The projections of applied water reductions and water conservation due to the EWMPs by 2020 are found in Table 7-14. These projections are included in the agricultural water demands shown in Table 7-15.

Recommendations

Gathering high-quality data to estimate applied water in agriculture and irrigation efficiencies entails a lot of cost and labor. A source of high-quality data about agricultural water use and conservation could be made available from local agricultural water management plans developed in accordance with the USBR water management reports and the planned EWMP program. Such a source currently exists from urban water agencies and is being strengthened through the BMP process. Specific recommendations are as follows:

1. State agencies should encourage and provide technical assistance to agricultural water suppliers in preparation and implementation of water management plans.
2. DWR needs to develop additional, more precise, on-farm applied-water data by crop to more accurately estimate agricultural applied water use efficiency in certain areas.
3. The State needs to determine the effect of increasing population on overall food production needs, in California and the nation, and its relationship to California's agricultural industry.

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Table 7-15. Agricultural Water Demand by Hydrologic Region
(thousands of acre-feet)

Hydrologic Region	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
North Coast								
Applied water demand	839	915	868	948	891	972	907	989
Net water demand	744	760	748	764	761	776	771	787
Depletion	592	647	611	669	627	686	637	698
San Francisco Bay								
Applied water demand	92	103	94	104	94	104	94	103
Net water demand	88	99	90	100	90	100	90	99
Depletion	80	89	82	90	82	90	82	89
Central Coast								
Applied water demand	1,140	1,178	1,166	1,206	1,182	1,220	1,189	1,233
Net water demand	893	961	910	982	920	991	921	1,003
Depletion	884	950	901	971	911	980	911	992
South Coast								
Applied water demand	727	753	632	655	499	518	382	396
Net water demand	644	668	569	592	458	474	356	370
Depletion	644	668	569	592	458	474	356	370
Sacramento River								
Applied water demand	7,848	8,645	7,698	8,517	7,592	8,475	7,558	8,333
Net water demand	6,788	7,394	6,602	7,222	6,506	7,184	6,497	7,049
Depletion	5,477	6,123	5,426	6,149	5,439	6,151	5,437	6,151
San Joaquin River								
Applied water demand	6,298	6,757	6,052	6,500	5,817	6,227	5,665	6,080
Net water demand	5,778	6,217	5,561	5,967	5,346	5,695	5,215	5,572
Depletion	4,719	5,064	4,605	4,909	4,490	4,777	4,383	4,678
Tulare Lake								
Applied water demand	9,613	9,849	9,306	9,518	9,075	9,281	8,833	9,038
Net water demand	7,723	7,895	7,518	7,685	7,347	7,505	7,169	7,320
Depletion	7,704	7,876	7,499	7,666	7,328	7,486	7,150	7,301
North Lahontan								
Applied water demand	522	587	523	589	525	591	536	602
Net water demand	460	511	458	510	457	508	469	521
Depletion	378	426	385	433	393	442	399	449
South Lahontan								
Applied water demand	317	321	266	270	258	262	253	257
Net water demand	290	293	242	245	235	238	231	234
Depletion	290	293	242	245	235	238	231	234
Colorado River								
Applied water demand	3,705	3,705	3,598	3,598	3,453	3,453	3,363	3,363
Net water demand	3,439	3,439	3,362	3,362	3,262	3,262	3,181	3,181
Depletion	3,439	3,439	3,362	3,362	3,262	3,262	3,181	3,181
TOTAL								
Applied water demand	31,100	32,800	30,200	31,900	29,400	31,100	28,800	30,400
Net water demand	26,800	28,200	26,100	27,400	25,400	26,700	24,900	26,100
Depletion	24,200	25,600	23,700	25,100	23,200	24,600	22,800	24,100

A stretch of the Trinity River. The river basin encompasses a watershed of almost 3,000 square miles in Trinity and Humboldt counties, and most of the river is protected under the federal Wild and Scenic Rivers Act. A U.S. Fish and Wildlife Service study is under way to establish the optimum flow schedule for fisheries in the Trinity River. The study is to be completed in 1996.

Chapter 8

Environmental Water Use

California has long led the nation in environmental awareness. Bulletin 3 (1957), California's first comprehensive water plan, noted what were then thought to be minimum fish flow requirements or operational requirements to maintain healthy fisheries on California's major stream systems impacted by water development. The recurrence of drought (both in 1976-77 and 1987-92) has shown that fish populations and wetland areas require a more dependable water supply. This will be the first water plan update to present environmental water needs along with urban and agricultural water demand.

Many of the State's biological resources are at low levels due to natural and human factors. Three runs (or races) of chinook salmon in the Central Valley and Klamath-Trinity river system have shown severe population declines in recent years. Two fish species in the Sacramento-San Joaquin Bay-Delta Estuary are at such low abundance levels that they are now protected under the State and federal Endangered Species Acts. Environmental organizations have prepared petitions to list longfin smelt and Sacramento splittail under the federal Endangered Species Act. The State Water Resources Control Board is conducting ongoing hearings to help determine if additional protection is needed for Bay-Delta Estuary fish and wildlife.

Governor Wilson, in his 1992 water policy, made it clear that fish and wildlife protection must be an integral part of the State's water management. He emphasized the need to balance the available water supply among often competing beneficial uses. As part of this balance, The Resources Agency proposed using "biodiversity regions," or "bioregions," in developing natural resource management plans. Biodiversity is an approach for maintaining habitat areas critical for a wide variety of plants and animals. Water is a vital component of habitats such as wetlands and riparian areas. Bioregions, including watersheds, transcend traditional jurisdictional lines and instead concentrate environmental planning and management on large, contiguous geographic areas with similar biological and physical components. Eleven bioregions were designated under a recent agreement signed by 10 State and federal agencies. The U.S. Fish and Wildlife Service is proposing a similar approach of multi-species, ecosystem planning.

This chapter contains separate sections about the Bay-Delta Estuary, instream flows, and wetlands. Brief descriptions of the physical and biological systems are provided. Current water requirements for protection of these systems are presented. Where current requirements do not fully meet environmental water needs, proposals for new allocations are presented if these are known. In many cases, there can be considerable controversy regarding the amount of additional water needed to meet environmental needs and whether it is in the public interest to fully meet these needs. Because of this controversy, which is exemplified by concerns about the Sacramento-San Joaquin River System, a range of 1 to 3 maf for proposed additional environmental water needs is presented.

Under the ESA biological opinions and proposed EPA Bay–Delta Standards, annual reductions in total water supply for urban and agricultural use could be in the range of 750,000 af to 1.3 maf in average years and 1.8 maf to 3.2 maf in critically dry years. As proposed in December 1993, EPA's estuarine standard would be met only 50 percent of the time at the 1.8-maf impact level. Unless the form of the standard is changed to an appropriate outflow regime, or to specify a suitable averaging period (for example, monthly), the analysis of impacts must include a buffer to move the compliance rate to 95 percent. A compliance rate of 95 percent would result in an impact of 3.2 maf in critically dry years. While these impacts do not consider the potential reductions in Delta exports due to *take limits* under the biological opinions, they basically fall within the 1- to 3-maf range for proposed additional environmental demands for protection and enhancement of aquatic species. Such uncertainty of water supply delivery and reliability will continue until issues involving the Delta and other long-term environmental water management concerns are resolved.

This chapter will not speculate on the outcome of proposed modifications to allocate additional water to the environment. Instead, a summary of existing and estimated environmental water requirements for major streams, the Sacramento–San Joaquin Bay–Delta Estuary, and wetlands is provided as well as proposals developed by DFG. The proposed additional requirements are included in a hypothetical range of 1 to 3 maf appearing in the water supply/water demand budget (Chapter 12), from which individuals can compare existing and proposed environmental water use with existing supplies and urban and agricultural demands. Allocation of water to streams, the Bay–Delta Estuary, and wetlands is generally by judicial and administrative processes as well as negotiations among affected parties.

This report only partially addresses the implementation of the federal CVP Improvement Act of 1992 as it relates to environmental water supplies since it will take several years to complete implementation of the Act. However, the legislation does contain several elements which will immediately affect the way in which water is used in California. The law requires specific amounts of water for fish and wildlife as well as stating goals for doubling existing anadromous fish populations affected by CVP operations. It is also State policy to significantly improve salmon and steelhead populations by the year 2000, as reflected in Section 6902 of the Fish and Game Code.

Bay–Delta Estuary

It is impossible to consider California's environmental water needs without discussing the Bay–Delta Estuary. Lying near the confluence of the Sacramento and San Joaquin rivers, this system of waterways comprises a Delta and a series of embayments leading to the Pacific Ocean at the Golden Gate (see Figure 8-1). This estuarine system has long been an important resource to California. Among the many factors affecting the estuarine environment are the rate and timing of fresh water inflow to the estuary, as well as the quantities of fresh water reaching it seasonally, annually, and over a series of years, and diversions from the estuary for both local and export uses. This section provides a description of the Bay–Delta Estuary, a brief history of the area, a review of the current environmental water requirements, and a summary of some of the current activities which may affect future fresh water allocations to the estuary (other aspects of the Delta are discussed in Chapter 10, *The Sacramento–San Joaquin Delta*).

Bay–Delta History

Before the Spanish arrived, several Native American tribes lived in the Bay–Delta area. Early settlements in the area expanded rapidly with the discovery of gold in the

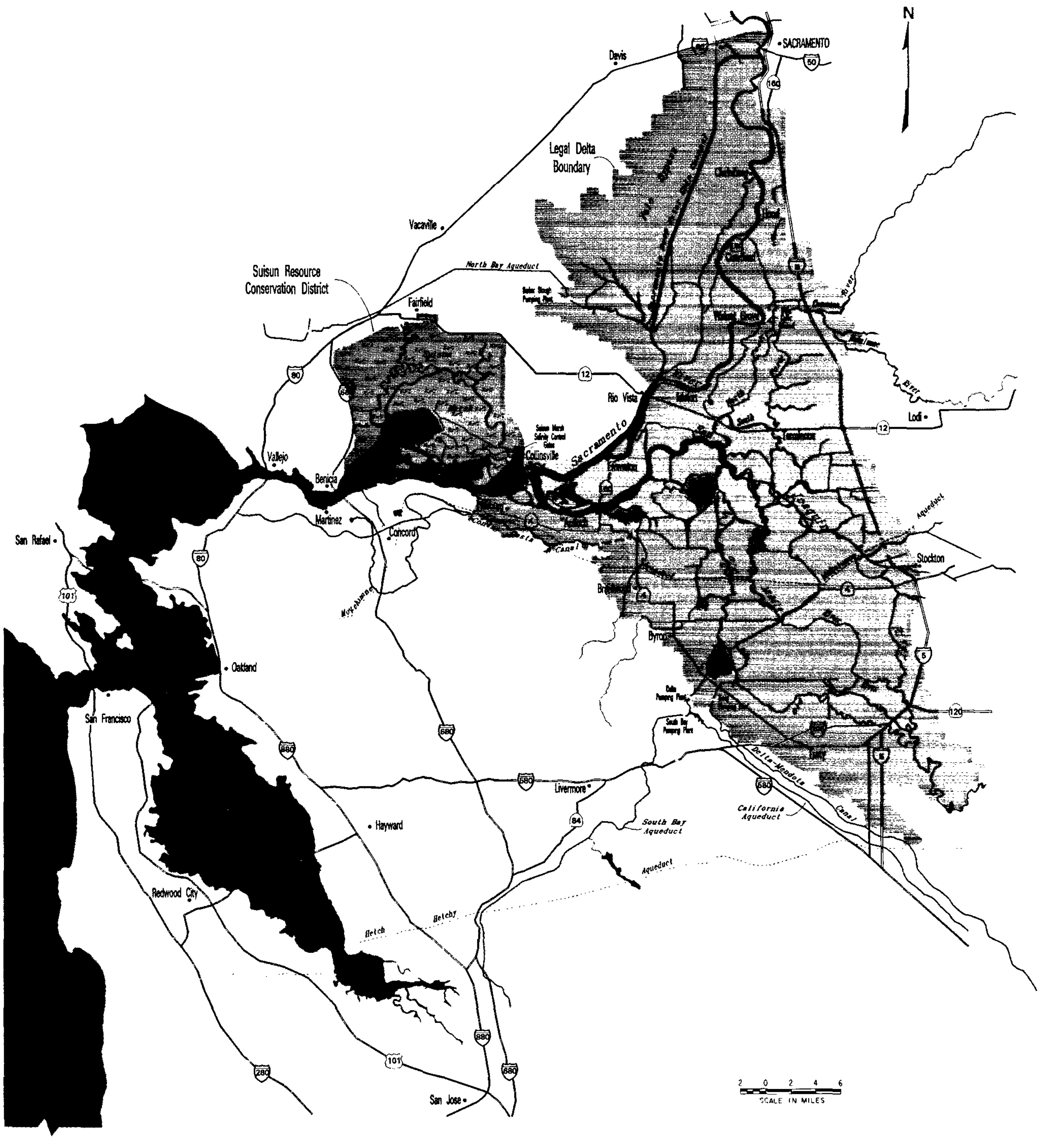
Sierra Nevada. Today, the Bay-Delta Estuary and its surrounding shorelines are home to about one-third of California's population. Water from the Delta provides part of the water supply for about two-thirds of the State's population.

During the mid-1800s, the rapid influx of new settlers and their activities resulted in almost immediate changes to the Bay and Delta. Edges of the Bay were filled to provide more land for homes and industry. Formerly flooded marshlands in the Delta were converted to farmable islands by building levees. Central Valley streams were dammed for water supply, valley lands were drained for farming, and hydraulic mining for gold in the watershed washed huge amounts of sediment into stream channels. All of these activities caused changes in the quantity and quality of water reaching the estuary. Finally, untreated municipal and industrial waste was discharged directly into the estuary.

Criteria for Summary of Present and Proposed Environmental Water Flows

1. The 1990-level instream fishery flows are based on existing water right permits, court decisions, congressional directives, laws or agreements between government agencies and project operators.
2. The 1990-level instream fishery flows for major streams (that is, rim stations for Central Valley streams), wild and scenic river flows, and required Delta outflow are presented in this report. Instream flows upstream of the major reservoirs are not listed.
3. Instream flow proposals are based on information provided by the Department of Fish and Game as part of the Department of Water Resources' State plan coordination. DFG supports proposed instream flows with biological studies showing the need for modification of current flows to protect or restore fish and wildlife.
4. Only flows specifically listed for instream fishery,wild and scenic rivers, and Delta outflow are considered in this chapter. Flows specifically designated for other instream use such as power generation and recreation are not evaluated under instream flow needs. Existing and proposed fish flows also include temperature and flow fluctuation criteria and ramping rates which could require additional water. In the interest of simplicity, these flows were not included in the environmental water need table.
5. Present instream flows, combined with wetlands water demands, are listed as environmental water needs and accounted for in the water balance.
6. Proposed instream flows are evaluated and presented as a "range of instream needs." The impacts of proposed flows on water supplies and water balance are noted and discussed in Chapter 12.
7. Instream needs are analyzed and listed in manners similar to those for urban and agricultural water demand by calculating applied water, net water, and depletion.
8. ET and ETAW on riparian lands adjacent to rivers are shared equally among agriculture, urban, and environmental users, and therefore are not accounted for under environmental water needs. This use and others such as ground water recharge are accounted for in the difference between the 200-maf annual statewide precipitation and the 71-maf annual statewide runoff.
9. For Central Valley streams, net water demands for each region are determined by examining controls at downstream locations and working back upstream. Depletion is computed as the portion of environmental water that enters a saline sink.

Figure 8-1. Sacramento–San Joaquin Delta and San Francisco Bay



The past 50 years have seen many new projects and activities affecting the Bay–Delta estuarine resources in various ways—some good, some bad, and some difficult to evaluate. Both San Francisco and East Bay Municipal Utility District built water export facilities upstream of the Delta to ensure high-quality water supplies to much of the Bay area. The federal Central Valley Project built dams on the Trinity River near Lewiston, on the Sacramento River near Redding, on the American River near Folsom, and on the San Joaquin River at Friant. In the 1940s and 1950s, the CVP began exports from the Delta through the Contra Costa Canal and the Delta-Mendota Canal. The State Water Project constructed Oroville Dam on the Feather River and Delta diversion facilities for the California and North Bay aqueducts. These developments, along with numerous local water developments on Central Valley tributary streams, caused changes in the timing and amount of Delta inflows and outflows during most years. Also, salmon runs were blocked from some of their traditional spawning areas and began spawning in streams made habitable by the cold water releases below the newly constructed dams and into fish hatcheries constructed to mitigate such impacts. Other races of salmon that spawned in the foothill elevations in some cases did not spawn successfully below these dams. For example, spring run salmon are no longer found in the San Joaquin drainage. In the case of the San Joaquin River below Friant Dam, no flows were allocated for salmon and all spawning and rearing habitat was lost.

Intensive efforts to reduce the effects of wastes discharged into the system accelerated after the federal Clean Water Act was signed in 1972. Better waste water treatment reduced the load of oxygen-consuming materials and some toxic substances to the Bay-Delta Estuary and improved conditions for fish and wildlife. While dredged material disposal (see Chapter 5) from deepening ship channels enhanced access to inland ports, it also presented potential adverse environmental impacts.

The Bay-Delta ecosystem has been changed dramatically by the accidental and purposeful introductions of numerous fish and invertebrate species. The purposeful introductions have included such species as striped bass, American shad, catfish, and largemouth bass. Accidental introductions arrived on shells of oysters and other bivalves or in ballast water of ships from foreign waters discharged to the estuary.

All the activities described above, plus natural events such as floods and droughts, have changed the estuarine ecosystem. It is often difficult to determine which factor is responsible for an observed change in the estuarine system, or if the change will be permanent, because many factors occur simultaneously. For discussion, the Bay-Delta Estuary system can be divided into three aspects: the physical system, water development, and biological resources and processes..

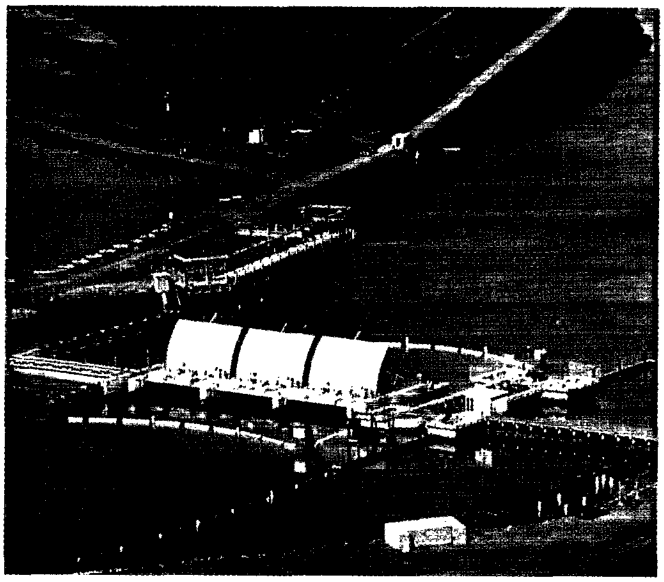
The Physical System

The physical system consists of the rivers, the Delta, the downstream embayments, and the Pacific Ocean. They all play important roles in determining the abundance and distribution of plants, fish, and wildlife in the estuary and must be considered as a whole.

The rivers flowing into and through the Delta play a multiple role in the estuary. In a simple sense, these rivers provide conduits for migratory fish, such as salmon, to move to and from the ocean; for other fish species, they provide spawning and nursery habitat. River inflow contributes much of the dissolved nutrients needed to support estuarine food chains. Fresh water from the rivers mixes with salt water from the ocean to create areas in the estuary where animals with varying salt tolerances can exist. Finally high fresh-water flow moves small life forms such as larval fish into the Suisun Bay.

The Delta contains about 700 miles of channels that provide habitat for numerous species of small plants and animals. The organisms form the basis for food chains that support more than 40 species of native and introduced fish. Presently, water in the Delta channels is generally fresh during all months of the year. Before water development, it was often salty from summer through late fall and outflows were higher in winter months. Delta waters are high in suspended matter because of the organic nature of Delta islands and annual sediment inflow. Often, light can only penetrate 2 feet or less; this high turbidity affects overall Delta productivity.

The first embayment below the Delta is Suisun Bay. This bay, which includes Grizzly and Honker bays, is the area where the effects of mixing seaward-flowing fresh water and landward-flowing saltwater (driven by tides) are most pronounced. Since saltwater is slightly heavier than fresh water, it tends to move landward under the river water, but this effect is only slightly seen in the upper bay and Delta. The complex circulation patterns cause a concentration of small plants, larval fish, and other animals within this zone. This area of concentration, a feature of all estuaries which receive significant amounts of fresh water, is called the entrapment zone, or zone of maximum turbidity. The location of the entrapment zone in the Suisun Bay and adjacent extensive areas of productive shallow water is considered to be an important ecological feature of the Bay-Delta Estuary complex. This zone moves upstream and downstream in the estuary depending on the amount of fresh water outflows.



Twice a day, Pacific Ocean tides move in and out of the Bay-Delta, bringing saltier water into the Suisun Marsh. Salinity control gates on Montezuma Slough Control Structure help maintain salinity standards set by the State Water Resources Control Board to protect habitat and water quality in this brackish water marsh.

Adjacent to Suisun Bay is the Suisun Marsh—about 80,000 acres of brackish water containing a significant percentage of the remaining contiguous wetlands in California. This managed marsh, and the other tidal wetlands around the Bay-Delta Estuary, provide valuable habitat for a variety of plants and animals, especially waterfowl. They also contribute significant amounts of nutrients to the estuarine system. (See the wetlands section later in this chapter.)

Below the Carquinez Strait are the San Pablo and central San Francisco bays. The Strait tends to isolate these bays from the Suisun Bay and the Delta and allows such oceanic conditions as tides to play a leading role in their salinity and circulation. During extremely high freshwater flows, such as happened during February 1986, these embayments can become quite fresh, especially at the surface. During these high flows, the entrapment zone can be temporarily relocated in San Pablo Bay. These embayments are quite saline at low fresh-water flows and high tides.

South San Francisco Bay is very different from the other parts of the system. This bay is out of the main path of Delta outflows and only receives significant flows from the Sacramento and San Joaquin rivers during high outflow or floods. Because of low freshwater flows during most of the year and losses of water through evaporation, the South Bay is often saltier than the ocean outside the Golden Gate. The South Bay does receive steady flows of secondarily treated municipal effluent and some local streamflow at its south end. The effluent is rich in nitrogen and phosphorus, which can stimulate algal growth. Changes in sewage treatment practices and outfall locations over the past 40 years have resulted in marked improvement in South Bay water quality. In the 1940s and 1950s, South Bay waters often had dissolved oxygen concentrations too low to support fish. These problems now occur only infrequently.

Tidal action moves water from the ocean into the Bay-Delta system through the narrow and deep Golden Gate. Although accurate estimates are difficult to obtain, one estimate is that about one-fourth of the Bay water is replaced with new ocean water during each complete tidal cycle. Physical processes in the ocean, including tides, horizontal currents along the coast which cause upwelling of deep oceanic water, temporary and long-term rises in sea level, and changes in ocean temperature, all affect the Bay-Delta ecosystem. In addition, many species of fish and fish-food organisms found in the estuary originate in offshore areas.

Water Development

Water development has changed the estuarine system in a variety of ways. Factors having the greatest influence are:

- Delta inflow
- Flows from the Sacramento River through the Delta Cross Channel
- Reverse flows
- Water project and local agricultural diversions
- Delta outflow and salinity

The effects of these changes on species can vary depending on the time of year and type of water year. Following are brief descriptions of how these factors can affect the Bay-Delta ecosystem.

The magnitude of flows coming down the rivers into the Bay-Delta estuary affects biological resources both in the rivers and in the estuary. For example, striped bass eggs and larvae are more likely to survive if flow rates in the Sacramento River are sufficient to transport the larvae downstream to Suisun Bay where food is more abundant. Juvenile salmon migrating out of the San Joaquin system are more likely to avoid the direct impacts of the pumps if they migrate down the San Joaquin River instead of Old River. Improved flows in the San Joaquin River would change the ratio of the flow split at the head of Old River and thus would increase salmon survival. The instream flows in the tributaries to the Delta are discussed in greater detail in later sections.

Some of the water flowing down the Sacramento River enters the lower San Joaquin River through Georgiana Slough, Three Mile Slough, and the Delta Cross Channel. Juvenile salmon migrating downstream in the spring can either move down the Sacramento River or through the Delta Cross Channel or Georgiana Slough. The salmon that remain in the Sacramento River have a better chance at survival than those that move through the Delta Cross Channel or Georgiana Slough.

The natural flow pattern in the estuary is for fresh water flowing to the ocean to cause the total flow during ebb tides to exceed the total flow during flood tides. The SWP/CVP pumps in the southwestern Delta can cause the total upstream flow during flood tide to exceed the total downstream flow during ebb tide. This is called reverse flow. The potential significance of reverse flow is that it tends to move fish and their food supply toward the SWP/CVP pumps rather than toward the ocean.

The CVP exports up to 4,600 cfs through the Tracy Pumping Plant and 250 cfs through the Contra Costa Canal. The SWP exports water up to 6,400 cfs through the Banks Pumping Plant and 150 cfs through the North Bay Aqueduct. Intakes at the Banks and Tracy pumping plants have louver fish screens that are ineffective for larval fish but are on the order of 90 percent effective for fish a few inches long. In addition to fish lost through the screens, some fish are also lost to predation and stress associated with handling and trucking. Calculated prescreening losses are high at the Banks Pumping Plant because of predation in Clifton Court Forebay. Losses at all facilities vary for different species and sizes of fish. In addition to losses at the SWP and CVP diversions, there are many unscreened agricultural diversions in the Delta and on the tributaries to the Delta that also cause fish losses.

There are two basic problems with the SWP and CVP screening facilities at their present locations. One is that fish must be captured and transported to another location for release. The other is that water is being withdrawn directly from the Delta, which is a major nursery for some fish and a permanent residence for others. The diversions can diminish the capacity of the Delta to support fish populations through effects on the fish and their food supply.

Delta outflow is the calculated amount of water flowing past Chipps Island, at the western edge of the Delta, into San Francisco Bay. The magnitude of Delta outflow controls the intrusion of salt water from the ocean into the estuary. Delta outflow and salinity intrusion are highly correlated. The magnitude of Delta outflow strongly influences the distribution of many estuarine fishes and invertebrates.

Generally, the greater the outflow, the further downstream estuarine fish and invertebrates occur. The relationship between Delta outflow and abundance of fish and invertebrates is not nearly as general. However, species such as longfin smelt and striped bass show strong correlations between abundance and Delta outflow.

Biological Resources and Processes

There is a complex interrelationship among several different food chains in the Bay-Delta ecosystem. Phytoplankton are plants that act as the grass of the estuary; their production depends on the availability of light and nutrients. Phytoplankton abundance in a particular location is determined by factors such as turbidity and the number of animals feeding on the algae. In the Delta, phytoplankton production is often limited by the amount of light penetrating the water. In Suisun Bay, the phytoplankton concentration is the highest when the entrapment zone is next to productive shallow areas. Since the mid-1970s, there has been a consistent and largely unexplained decline in most phytoplankton abundance in the Delta and Suisun Bay. This decline could affect the estuary's ability to support fish.

Although phytoplankton play an important role in the estuary, their exact contribution has not been well documented. Rivers and marshes contribute organic particles (such as leaves and grasses) which may also be significant sources of energy for the next level of the food chain, zooplankton or the grazers. Zooplankton capture live or decomposed plant and animal material for their food. In recent years, many of the native zooplankton in the water column have declined in the Delta and Suisun Bay. These declines were often accompanied by increases in accidentally introduced zooplankton and a species of clam (*Potamocorbula amurensis*) which has colonized Suisun Bay. Although the exact impacts of these introductions have not been defined, they have undoubtedly changed the food web.

More than 100 species of fish use the Bay-Delta system. Some are year-round residents, such as Delta smelt and catfish, while others, such as American shad, are in the estuary for only a few months. Some of the species can live only in relatively fresh water and others can only survive in the more saline parts of the Bay. There are also several fish with intermediate salinity tolerance; these are the true estuarine species. Finally, there is a mixture of native and introduced species. The most notable of the introduced species is the striped bass; the chinook salmon is one of the more well-known native fishes. Introductions, both planned and accidental, have changed the Delta fish fauna to the point that native species now make up only 40 percent of the fish species and even less of the total population of fish.

An overview of the status and trends of several key fish populations is provided including striped bass, winter-run chinook salmon, fall-run chinook salmon, Delta smelt, longfin smelt, and the Sacramento splittail. These species are discussed because they are the focus of many efforts to restore the Delta ecosystem. Other fish showing declines are the white catfish, sturgeon, and the starry flounder.

Striped Bass. Stripers flourished after their introduction in the late 19th century. However, since the early 1960s, the adult population has declined from an estimated 3 million to less than 1 million. (Figure 8-2 illustrates the decline of one of the striped bass life stages, the stage when they are about $1\,^1/_2$ inches long.) One of the principal environmental goals of the SWRCB's D-1485, enacted in 1978, was to halt the decline and restore the population to "without project" levels. This goal was not realized, in part because the Bay-Delta has continued to change.

The reasons for the observed declines are difficult to determine. Water project exports, drought, unscreened agricultural diversions in the Delta, ocean fishing, illegal fishing, toxics, and exotic species (some of which affect the food chain) are all factors.

Winter-Run Chinook Salmon. One of four runs of chinook salmon inhabiting Central Valley streams is the winter-run chinook salmon. The other runs also are named after the time the adults migrate through the Bay-Delta on their way upstream to spawn: these are the spring, fall, and late fall-runs.

The winter-run is unique among the other chinook salmon races around the Pacific Rim because it spawns during the late spring and summer. Historically, this race migrated to tributaries in the headwaters of the Sacramento, Pit, and McCloud

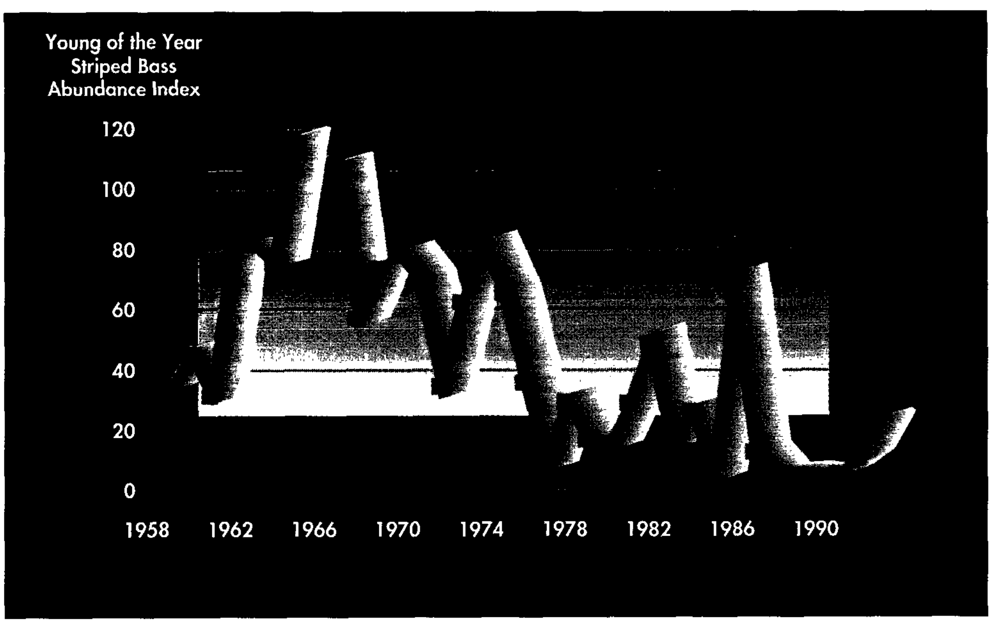


Figure 8-2. Striped Bass Abundance Sacramento-San Joaquin Estuary

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rivers where cool mountain springs provided suitable temperatures for egg incubation and juvenile rearing during the summer months. The juveniles probably moved out to the ocean in late fall and winter, and returned as adults two to four years later. Run sizes earlier this century are not well documented, but information from just prior to construction of Shasta Reservoir indicate that the run was probably small at that time. However, much larger runs were reported in the late 1800s. Although Shasta Dam completion in 1944 blocked access to their historical spawning grounds, releases of cold water from the reservoir enabled the fish to reestablish themselves in the reach of the Sacramento River below Keswick Dam to as far downstream as Red Bluff.

DFG first estimated populations of adult winter-run spawners in 1966, after the Red Bluff Diversion Dam was constructed. The dam forced upstream migrating adults to go past counting windows installed in fish ladders at both ends of the dam. The population has exhibited a decline over the past 25 years, with the low point of 200 estimated spawners in 1991 (see Table 8-1). There were 1,180 estimated spawners in 1992 and 341 in 1993. In response to the declines, winter-run chinook salmon were listed as *threatened* by the National Marine Fisheries Service under the federal Endangered Species Act in November 1990, reclassified as *endangered* in 1994 by the NMFS, and classified as *endangered* by the Department of Fish and Game under the California Endangered Species Act in October 1989.

The USBR is taking steps to permanently improve Shasta Dam's cold water release capability under changing reservoir storage levels to increase winter- and fall-run survival. Installation and operation of a temperature control device at Shasta Dam is one of the fish and wildlife restoration activities required by the CVPIA and would decrease the amount of water that would need to be dedicated for protection of the winter-run.

In 1991, the USBR and DWR began consultation with NMFS and DFG to assess the impacts of the CVP and SWP on the winter-run chinook salmon. On February 14, 1992, NMFS issued its Biological Opinion, which recommended a reasonable and prudent alternative that, if implemented, would avoid jeopardizing the continued existence of the winter-run chinook salmon. Reasonable and prudent measures to avoid and minimize the effects of the CVP's and SWP's incidental taking of winter-run were also provided to the USBR and DWR.

The reasonable and prudent alternatives and the reasonable and prudent measures included modifying CVP operations to provide cold water in spawning and nursery grounds, controlling flows in the Sacramento River, closing the Delta Cross-Channel, and stopping operation of the Montezuma Slough Salinity Control Gates.

Table 8-1. Estimated Winter Run Chinook Salmon at Red Bluff Diversion Dam

Year	Number of Fish	Year	Number of Fish	Year	Number of Fish
1967	57,300	1976	35,100	1985	4,000
1968	84,400	1977	17,200	1986	2,400
1969	117,800	1978	24,900	1987	2,000
1970	40,400	1979	2,400	1988	2,100
1971	53,100	1980	1,200	1989	500
1972	37,100	1981	20,000	1990	400
1973	24,100	1982	1,200	1991	200
1974	21,900	1983	1,800	1992	1,180
1975	23,400	1984	2,700	1993	341

Measures were also taken at the Tracy and Banks pumping facilities to reduce losses of winter-run juveniles due to diversion. In April 1992, in response to an increased take of winter-run at the pumps over that which had been anticipated in the Opinion, NMFS set specific limits on allowable take from April 9–30. To comply with the take limitations, pumping was curtailed by both projects.

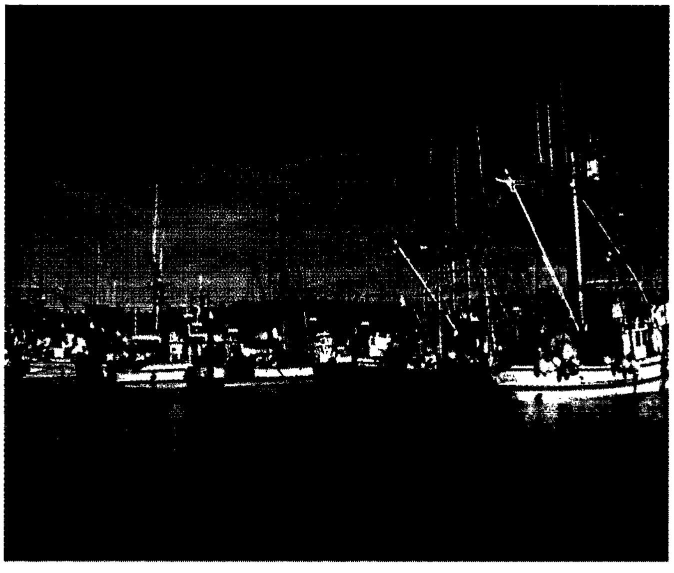
In September 1992, NMFS convened a Recovery Team to develop a Federal Recovery Plan for the winter-run chinook salmon. The team consists of academicians (population biologists and geneticists) and representatives of the State and federal fishery agencies.

NMFS released its long-term biological opinion on February 12, 1993, which was subsequently adopted by DFG. Conditions were similar to those contained in the 1992 opinion. However, the opinion for long-term operations contained a numerical limit on take of juvenile winter-run at the Banks and Tracy pumping plants as well as standards on flow in the lower San Joaquin River. To comply with the take limitations in the winter of 1993 and the flow standards in the lower San Joaquin River, the SWP curtailed pumping in February and March while there were high flows into the Delta.

NMFS, USFWS, and DFG are implementing recovery efforts to protect and restore the winter-run chinook salmon. These include restricting in-river and ocean harvest, reducing losses to diversions along the Sacramento River (for example, intakes to Anderson-Cottonwood and Glenn-Colusa Irrigation districts), artificial propagation, and a captive breeding program. The goal of the artificial propagation and captive breeding program is to protect against loss of genetic diversity and possible extinction due to low population levels in the wild.

Fall-Run Chinook Salmon. Both the Sacramento and San Joaquin river systems support fall-run chinook salmon, the run that provides the majority of the fish taken in the commercial and sport harvest and is the predominant run in California today. The adult salmon move upstream and spawn in the fall months, the eggs incubate during the winter months, and the juveniles migrate downstream in the late winter and spring months. Factors that can affect the number of fall-run chinook salmon returning each year to spawn include habitat conditions in the tributaries, losses to diversions and pollution, losses in the Delta during outmigration, and sport and commercial harvest.

Sport and commercial harvest of salmon are the basis of a multi-million-dollar industry. Commercial harvest is regulated by the Pacific Fisheries Management Council, and sport harvest is regulated by the Fish and Game Commission. Regulations are set each year to meet the salmon spawning stock escapement goals. Recently, the target escapement for the



Salmon trawlers in Crescent City's marina. Commercial and sport fishing are an integral part of the area's economy.

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Sacramento system has been 120,000 to 180,000 salmon. The number of salmon taken by sport and commercial harvest for the period 1971 through 1991 is shown in Figure 8-3. Because the bulk of the harvest consists of three–year–old fish, the salmon harvest numbers reflect spawning conditions of three years earlier, as well as ocean conditions during the same period. The salmon harvest of 1988 was nearly 300 percent higher than in 1983–84, a period of low harvest. For comparison, just after the first 6–year drought of this century (1929–34), a biological report and investigation on the salmon fishery in the Sacramento River near the Shasta Dam site (prepared by the U.S. Bureau of Fisheries in 1940) indicated that salmon catches had "...already undergone a serious decline...." and that the salmon count past Redding in 1939 was estimated at 27,000. Sacramento Valley fall chinook have not met their escapement goals in the past three years, and the Pacific Fisheries Management Council has convened a work group to examine reasons for the low runs. (See Figure 8-4 for runs on other rivers.)

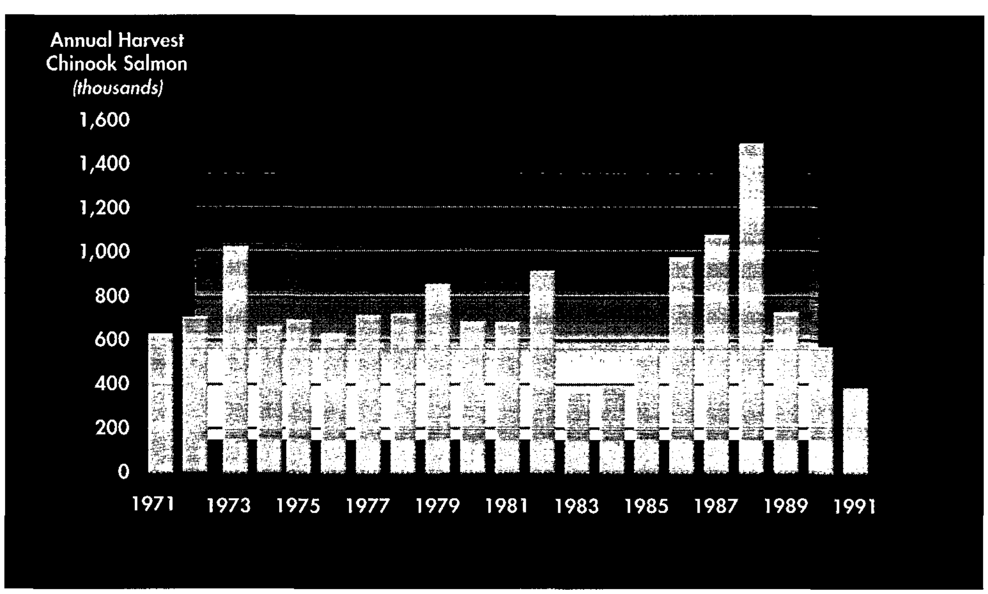
The causes of the declines in salmon populations are the subject of great debate, and all parties do not agree on the relative importance of the different factors including harvest, poaching, instream flows in the tributaries, gravel quality, predation by non–native species, losses at unscreened water diversions, mortality in the Delta, pollution, and other factors related to changes in land use management. It is likely that all these factors have played a role in the overall health of the salmon fishery.

Hatcheries on the Sacramento, Feather, American, Mokelumne, and Merced rivers augment the natural salmon production in the Central Valley. Juvenile salmon produced in these hatcheries are regularly trucked downstream and released below the Delta ,while juvenile salmon produced by in–river spawning migrate downstream and are influenced by factors such as diversions and changes in Delta conditions.

The Feather River is one of the brighter spots in the Central Valley salmon picture. Fall and spring chinook use the river for spawning and the Feather River Hatchery propagates both races. The size of the run on this river is generally larger than it was during the years prior to construction of Oroville Dam (see Table 8-2). The Feather River fall-run also has been estimated to contribute up to one–fourth of the commercial salmon catches originating from Central Valley salmon stock.

Figure 8-3. Estimated Annual Ocean Harvest of Chinook Salmon 1971–1991 (thousands)

Estimated totals include harvest from ocean commercial (troll) and sport (charter boat and skiff) fishing.



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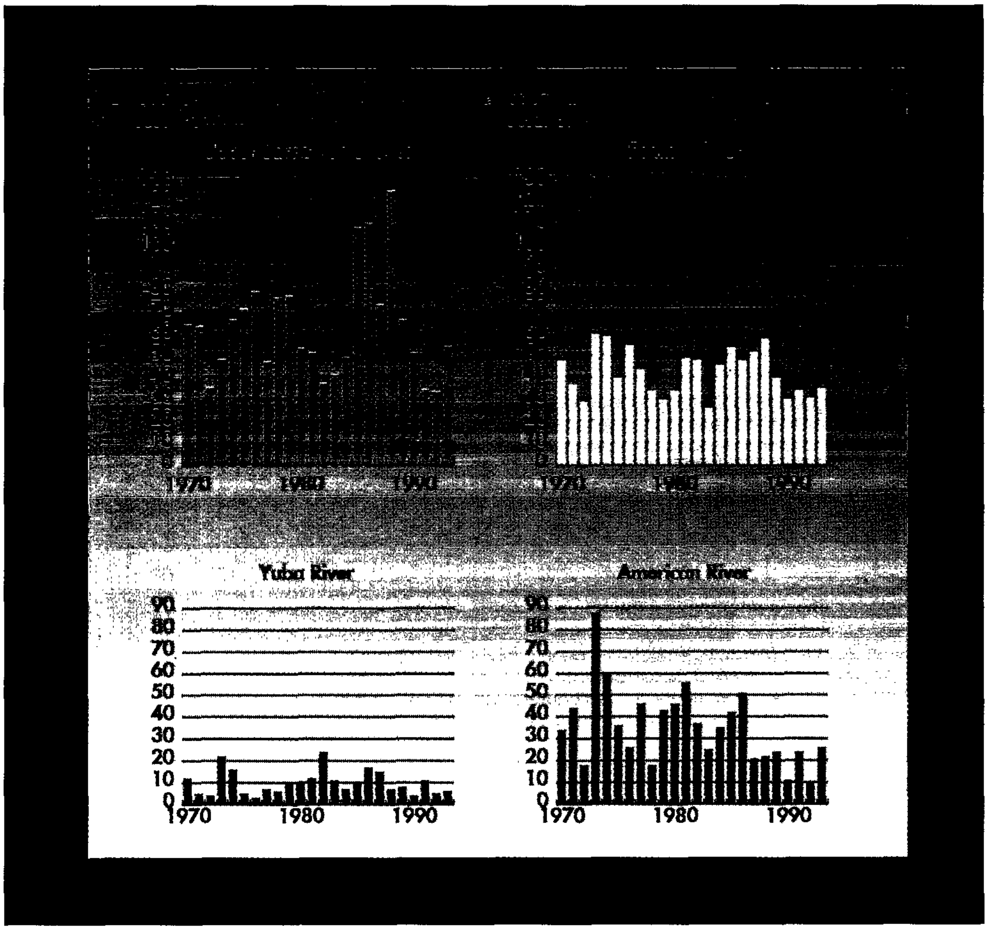

Figure 8-4. Fall-Chinook Salmon Runs on the Sacramento River and Tributaries

There are other factors affecting the general abundance of chinook salmon in California's rivers and streams. Droughts reduce stream flow and thus habitat required to support salmon. At the same time, salmon harvests reduce the number of returning adult salmon to California's streams and rivers. Figure 8-3 shows the chinook salmon landed by troll fishing in California from 1971 through 1991.

Table 8-2. Estimated Fall Run Chinook Salmon in the Feather River

Year	Number of Fish	Year	Number of Fish	Year	Number of Fish
1953	28,000	1965	23,200	1977	57,300
1954	68,000	1966	21,000	1978	43,200
1955	86,000	1967	12,000	1979	36,400
1956	18,000	1968	18,000	1980	40,400
1957	10,000	1969	61,000	1981	59,100
1958	32,000	1970	62,000	1982	64,200
1959	76,000	1971	47,000	1983	37,200
1960	79,000	1972	47,000	1984	61,600
1961	43,500	1973	74,000	1985	63,900
1962	18,500	1974	66,000	1986	63,200
1963	34,000	1975	43,000	1987	79,000
1964	38,400	1976	62,000	1988	69,400

Delta Smelt. In contrast to the chinook salmon, which undergo an extensive migration to and from spawning grounds and the Pacific Ocean, the delta smelt generally spends its entire life cycle in the Sacramento–San Joaquin Delta and Suisun Bay. The Delta smelt is small (maximum length about 5 inches), rarely lives more than one year, and is not taken in recreational or commercial fisheries.

It is impractical to obtain accurate estimates of delta smelt abundance in the estuary at any given time. Instead, DFG determines annual indices of abundance as part of the striped bass sampling by towing the same kind of net at the same time and location each year. These indices show a delta smelt decline to low population levels in the early 1980s which have generally stayed low through 1991. One index, the fall abundance, shows a consistent increase from 1988 through 1991. In 1992, the fall delta smelt index again declined to lower levels but returned to higher levels in 1993.

In 1990, the California Fish and Game Commission rejected a petition to list the delta smelt as endangered. That same year, the California–Nevada Chapter of the American Fisheries Society submitted a similar petition to the USFWS. USFWS announced its decision to list delta smelt as threatened on March 4, 1993 (effective on April 5, 1993) and issued a formal biological opinion for SWP and CVP operations on May 27, 1993. USFWS issued another biological opinion for SWP and CVP operations on February 4, 1994.

Longfin Smelt and Sacramento Splittail. The status of several other fish species may soon be affecting water project planning and operation. In November 1992, a coalition of environmental groups submitted a petition to USFWS to list the longfin smelt and the Sacramento splittail. The longfin smelt spends its life cycle in the estuary and moves from San Pablo Bay through Suisun Bay to spawn in the Delta and Suisun Bay. The splittail generally spends most of its life cycle in the Delta; there is also a population in the Delta–Mendota Canal. In both instances, increased abundance is positively correlated to high storm flows during the late winter/spring period.

In 1989, DFG released a report describing the status of 45 fish species of special concern in California. Two Central Valley salmonids, the spring run on the Sacramento River and its tributaries, and the fall-run on the San Joaquin, are in particular trouble. It is clear that the water needs of threatened and endangered fish and other aquatic species, along with factors affecting aquatic species must be taken into consideration as California plans for future water supplies.

Bay–Delta Environmental Water Needs

The SWRCB, through its water rights process, has been the principal forum for establishing the Bay–Delta's environmental water requirements. (Requirements as used here means actions taken by regulatory agencies to allocate water for various beneficial uses, whereas water needs are the demands for water.) The SWRCB has reserved jurisdiction in water rights permits and periodically holds water rights hearings in which interested agencies and parties provide evidence supporting their respective views regarding the water rights, public interest, or public trust impacts of the permitted use. The SWRCB then sets standards and operating criteria to provide balanced protection to all recognized beneficial uses. The State and federal projects are currently operating under FESA requirements in addition to SWRCB Decision 1485, issued in 1978.

The exact amount of water which may be ultimately required to meet Bay–Delta environmental needs will not be known until many of the processes currently under way are completed. The difficulty in predicting the amount of water that may be dedicated to environmental protection is complicated by the variety of ways that may evolve to correct problems associated with the Delta ecosystem and the conveyance of water through the Delta for export. (See Chapter 10 for an explanation.) Federal and State fisheries agencies, the federal EPA, and environmental organizations have made recommendations which could substantially increase the amount of water allocated to protect the Bay–Delta's environmental resources. In light of the many factors influencing water availability in the Delta, a range of environmental water needs was estimated at 1 to 3 maf annually. The potential environmental water needs are included in the California water budget discussed in Chapter 12.

Other Activities That May Affect Bay–Delta Water Allocation

There are several other forums and activities that can potentially influence the amount of water reaching the estuary. The San Francisco Estuary Project was a multi-agency effort to develop a management plan for the Bay–Delta Estuary. The project was authorized under Section 320 of the federal Clean Water Act and resulted in a comprehensive conservation and management plan for the estuary.

The U.S. Environmental Protection Agency is considering promulgating Bay-Delta standards based on its rejection of water quality standards developed by the SWRCB. One significant proposed standard would be for flows needed to position a specified bottom salinity, 2 parts per thousand, at various locations along the Suisun Bay to the western Delta, depending on the amount of natural runoff. Another would be to specify conditions leading to increased survival of juvenile chinook salmon through the estuary. If implemented, these standards would reduce or reallocate project yield substantially while increasing protection for aquatic species.

The Governor created the Bay–Delta Oversight Council as part of his 1992 water policy. The council, consisting of representatives from urban, agricultural, and environmental water user groups, is to investigate facilities, operations, and other measures that can provide a stable water supply and protect the Bay–Delta environmental resources.

Future facilities may also play a key role in determining environmental water needs for the Bay–Delta. These facilities include those in the Delta itself that are designed to eliminate some of the problems now caused by Delta diversions. Facilities south of the Delta can be used to store water during peak availability times when environmental impacts may be minimal. Chapter 10 discusses options for fixing the Delta and accompanying water supply benefits. Facilities upstream of the Delta, such as the Shasta Dam temperature control device, can also change environmental water needs.

Environmental Instream Flows

Environmental instream flow is the water maintained in a stream or river for instream beneficial uses such as fisheries, wildlife, aesthetics, recreation, and navigation. It is one of the major factors influencing the productivity and diversity of California's rivers and streams. For wildlife, instream flow sustains the stream bank and floodplain riparian zones and provides aquatic food resources (e.g., fish, invertebrates, and plants). It has a direct effect on fisheries by creating riffles, pools, and glides as habitat for game and nongame species. Instream flow is also important because it provides a corridor for migratory aquatic species to reach upstream spawning and rearing habitat. Many organisms, especially invertebrates, depend on streamflow to deliver their food. Instream flow also has a vital role in maintaining water quality for aquatic species. It helps sustain proper water temperatures and oxygen levels and serves to remove natural sediment and agricultural, municipal, or industrial wastes that could otherwise accumulate in the system.

Table 8-3. Summary of Present and Proposed Fishery Flows for Major California River Systems

River Location	Status	Water Year Type	Minimum Streamflow (cfs) OCT 1-14	OCT 15-31	NOV	DEC 1-15	DEC 16-31	JAN	FEB
Klamath									
Iron Gate Dam	Present	All	1300	1300	1300	1300	1300	1300	1300
Trinity									
Lewiston Dam	Present[1]	All	300	300	300	300	300	300	300
Sacramento		Dry – Wet	3250	3250	3250	3250	3250	3250	3250
Keswick Dam/	Present[2]	Critical	2800	2800	2800	2000	2000	2000	2000
Red Bluff/Keswick	Proposed[3]	Dry – Wet	4500	4500	4500	4500	4500	4500	4500
		Critical	3500	3500	3500	3500	3500	3500	3500
Yuba									
Smartville	Present*	Runoff ≥ 50%	0	600	600	600	600	800	600
Daguerre	Present	Runoff ≥ 50%	400	400	400	400	400	245	245
Marysville	Proposed[4]	Full local supply	700	700	700	700	700	700	700
Feather	Present[5]	Runoff ≥ 55%	1700	1700	1700	1700	1700	1700	1700
Below Thermalito		Runoff ≥ 55%	1200	1200	1200	1200	1200	1200	1000
Afterbay	Proposed[6]	All	1000	1700	1700	1700	1700	2000	2000
American	Present[7]	All	500	500	500	500	500	250	250
Lower American	Proposed[8]	All	1750	2000	2000	2000	2000	2000	2000
Sacramento	Present[9]	Critical	1500	1500	1500	1500	1500	1500	1000
Rio Vista		Wet	5000	5000	5000	5000	5000	2500	3000
Mokelumne Camanche	Present [5]	All	0	0	50	66	66	40	30
Woodbridge	Proposed[10]	Wet	300	350	350	350	350	350	350
		Normal	250	300	300	300	300	300	300
		Dry	20	20	200	200	200	200	200
Stanislaus	Present[11]	Normal	200	200	200	200	200	125	125
Goodwin Dam		Dry	150	150	150	150	150	100	100
	Proposed	Critical – Wet	200-300	250-400	250-400	250-400	250-400	200-400	200-400
Tuolumne	Present[12,13]	Dry – Wet	150-200	200-300	200-300	150-250	150-250	150-250	250
New Don Pedro Dam		Critical	50	200	200	200	135	135	135
	Proposed[14]	Critical – Wet	80-300	80-300	80-300	80-300	80-300	80-300	80-300
Merced	Present[15]	Normal	25	75	180-220	180-220	180-220	180-220	180-220
Shaffer Bridge		Dry	15	60	180-220	180-220	180-220	180-220	180-220
	Proposed[16]	Critical – Wet	200-300	250-350	250-350	250-350	250-350	200-350	200-350
San Joaquin River	Present[17]	All	0	0	0	0	0	0	0
Friant[18]	Present	All	0	0	0	0	0	0	0
Vernalis	Proposed[17]		0	0	0	0	0	0	0

1. The USBR and USFWS agreement requires 340,000 acre-feet per year of flow from 1991.
2 Additional peaking inflows required Dec. 1 – May 1 for fish spawning, egg incubation, outmigration, and temperature maintenance. Streamflow reduction criteria also exist, as well as the temperature requirements set in SWRCB Order 90-5.
3. Preliminary flows based on Department of Fish and Game staff recommendations. New recommendations may follow implementation of instream flow study.
4 Streamflow reduction criteria recommended at 800-1500 cfs from Oct. 15 – Feb. 1 and all flows in May and June. Additional streamflow may be required to maintain temperature standards.
5. Streamflow reduction standards exist in all months.
6. Preliminary flows based on Department of Fish and Game staff recommendations. New recommendations may follow completion of instream flow study.
7. SWRCB Decision 893. In better hydrologic conditions, USBR tries to operate on modified Decision 1400, resulting in considerably higher flows
8 Based on EBMUD Court Decision. Recommendation may be altered following completion of instream flow study. There are numerous other potential instream flow scenarios for the Lower American River
9. Standards from SWRCB D-1485.
* A 1993 FERC order for PG&E operation of Narrows 1 Power Plant at Englebright Reservoir provides for flow rates at Smartville up to the monthly amounts proposed in 1991 by DFG for Marysville limited to a maximum incremental storage release of 45,000 af annually.

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Table 8-3. Summary of Present and Proposed Fishery Flows for Major California River Systems

Minimum Streamflow (cfs)											
MAR *1-15*	***MAR*** *16-31*	***APR*** *1-15*	***APR*** *16-30*	***MAY*** *1-15*	***MAY*** *16-21*	***JUNE***	***JULY***	***AUG***	***SEP*** *1-14*	***SEP*** *15-30*	***Source***
1300	1300	1300	1300	1000	1000	710	710	1000	1300	1300	DWR 1982
300	300	300	300	300	300	300	300	300	300	300	USDOI 1991
2300	2300	2300	2300	2300	2300	2300	2300	2300	3250	3250	SWRCB 1990
2300	2300	2300	2300	2300	2300	2300	2300	2300	2800	2800	1960
4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	DFG 1992
3500	3500	3500	3500	4000	4000	4000	4000	4000	4000	4000	
600	0	0	0	0	0	0	0	0	0	0	DFG 1962
245	245	245	245	245	245	245	70	70	70	70	DFG 1965
700	700	1000	1000	2000	2000	1500	450	450	450	450	DFG 1991
1700	1700	1000	1000	1000	1000	1000	1000	1000	1000	1000	DWR/DFG 1983
1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	DFG 1983
2000	2000	2000	2000	3000	4000	4000	1000	1000	1000	1000	DFG 1992
250	250	250	250	250	250	250	250	250	500	500	SWRCB 1958
3000	3000	3000	3000	3000	3000	3000	1750	1750	1750	1750	Judge Hodge
1000	2000	2000	2000	2000	2000	2000	1000	1000	1500	1500	SWRCB 1978
3000	5000	5000	5000	5000	5000	5000	3000	1000	5000	5000	
30	30	0	0	0	0	0	0	0	0	0	DFG 1961
400	400	450	450	450	450	300	300	300	300	300	DFG 1991
350	350	400	400	450	450	400	150	100	100	100	
200	200	200	250	300	300	20	20	20	20	20	
125	125	125	125	125	125	150	150	150	150	150	DWR 1982
100	100	100	100	100	100	50	50	50	50	50	DFG et al 1987
200-350	200-350	300-500	300-500	300-500	300-500	200-350	200-350	200-350	200-350	200-350	DFG 1992
300-350	300-350	250-550	250-550	100-200	100-200	3	3	3	3	3	FERC 1986
200	200	85	85	3	3	3	3	3	3	3	FERC 1964
80-300	80-300	80-550	80-3000	80-3000	80-3000	50-200	50-200	50-200	50-200	50-200	DFG 1992
180-220	180-220	75	75	75	75	25	25	25	25	25	DWR/MID 1968
180-220	180-220	60	60	60	60	15	15	15	15	15	
200-350	200-350	300-500	300-500	300-500	300-500	200-350	200-350	200-350	200-350	200-350	DFG 1991
0	0	0	0	0	0	0	0	0	0	0	SWRCB 1978
0	0	0	0	0	0	0	0	0	0	0	SWRCB 1959
0	0	2K-10K	2K-10K	0	0	0	0	0	0	0	DFG 1992

10. Spawning attraction, outmigration, and streamflow reduction criteria recommended for Oct. 1 – Nov. 15, April 1 – June 30, and Oct. 1 – Feb. 29, respectively. Short-term reduction criteria also recommended. Proposed fishery flows for the Lower Mokelumne River would, at times, exceed the available supplies. There are also alternative flow schedules proposed by the City of San Francisco and by the USFWS.

11. Instream flow is also influenced by water quality standards in the San Joaquin River. Streamflow is renegotiated annually for a 7-year fisheries study and includes a minimum 98,000 AF fisheries allocation from Public Law 87-874.

12. Preseason flushing flow standards also exist.

13. Additional flow is required for fisheries studies.

14. These ranges summarize ten possible flow schedules for a 10-year fisheries study. The exact schedule is determined by the projected inflow. Flows will be altered following completion of fisheries study. There are also alternative flow schedules proposed by EBMUD and by FERC.

15. Criteria also exist to minimize streamflow fluctuation.

16. Flows developed for planning purposes for Montgomery/New Exchequer Reservoir operation. Additional recommendations to follow completion of instream flow study.

17. Additional flow required to meet water quality standards in SWRCB Decision 1422.

18. Decision 935

Note K = 1,000

Identifying instream flow needs for fisheries is one of the greatest challenges for resource managers. Rivers are complex systems that contain diverse and interrelated physical, chemical, and biological characteristics. Identifying flow needs for even a single type of fish is often difficult because its habitat needs may vary seasonally for different life stages. Prior to 1970, the professional judgment of resource managers was the primary means for recommending minimum instream flows. Because more standardized, quantitative methods of analysis were desired in order to better define and balance increasingly competitive demands for water, scientists developed the Instream Flow Incremental Methodology, which is now one of the most frequently applied systems to analyze fishery and recreation flow needs.

IFIM is not a single method, but rather a conceptual framework that includes a number of different techniques. The basic assumption of most IFIM studies is that the amount of habitat existing at different flow levels can be estimated and used to help make flow recommendations. In this context, habitat is defined as all areas in the river with the necessary physical and chemical conditions to support a species. Suitable habitat occurs when there is the proper combination of water velocity, depth, substrate, cover, and water quality.

An important advantage of IFIM is that it allows an incremental analysis of the amount of suitable habitat for fish (or other organisms) at different flows. This creates an important tool for water resource negotiations, where quantified and well-documented information on the possible effects of flow changes on fisheries is needed. The IFIM is not universally accepted. IFIM focuses on fish habitat, not fish production, and if the amount of habitat is the limiting factor, then the fish population should increase when the available habitat increases. However, if the amount of habitat is adequate and another factor, such as increased fishing, is limiting the population, a fish population will not necessarily increase with increased habitat. Nonetheless, the IFIM is the most widely accepted tool to help determine instream flow requirements and is frequently used for decision making and negotiation.

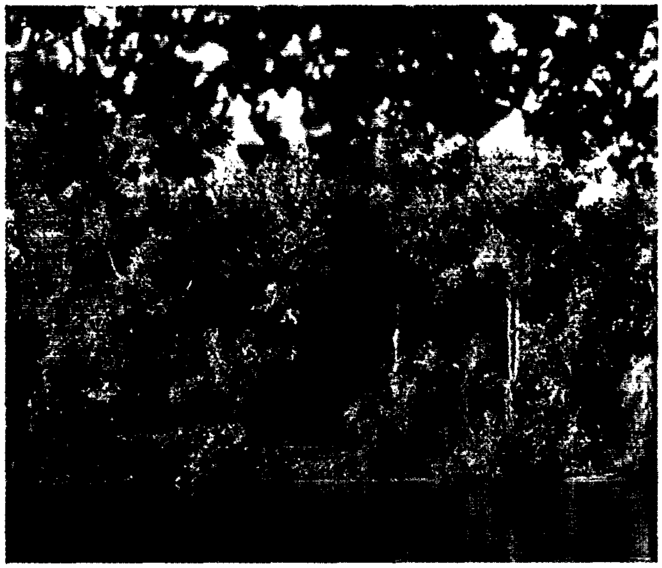
Recognizing the necessity for adequate instream flow for maintaining California's fisheries, riparian areas, and recreation, federal and State resource agencies are in the process of trying to determine needed stream flows for much of California. Table 8-3 summarizes existing instream fishery flow regulatory requirements and proposed recommendations by resource agencies for the Klamath, Sacramento, and San Joaquin river systems. The existing regulatory requirements are listed for each river, followed by a summary of proposed additional environmental water needs, where recommendations are available. In many cases, the existing requirements and recommendations also include flows specifically designated for riparian and appropriative water users rather than instream environmental uses. Nonetheless, these flows often benefit fish and wildlife as well.

The following sections present a more detailed discussion of selected rivers to illustrate the diversity of instream flow issues and progress made in resolving them.

Sacramento River Region

The Sacramento River and its tributaries discharge into the estuary and provide habitat for fish and wildlife. The following discussion focuses on instream flow in the mainstem and one of its tributaries, the Feather River (and a tributary to the Feather, the Yuba River). The discussion also focuses on the chinook salmon.

Sacramento River. The Sacramento River below Keswick Dam provides habitat for a number of migratory game species including spring, fall, late-fall, and winter-run chinook salmon; steelhead trout; and American shad. Fall run salmon constitute the largest fishery resource in the region, but winter-run salmon are particularly important because they are listed as endangered species under both the federal and State Endangered Species acts.



Riparian habitat along the Sacramento River. The Sacramento River Region supports the most productive salmon fishery in California.

Flows are set by a DFG/USBR agreement for Keswick and Shasta dams' management and a more recent agreement to stabilize flows from September to December. The criteria include average daily flows for fish spawning and rearing, and limits on flow fluctuations to avoid the dewatering of redds (salmon nests). Flows are also regulated by SWRCB Decision 90-5 which set temperature requirements to protect winter-run salmon spawning.

Several environmental problems have been recognized in the system; however, most of the recent focus has been on winter-run chinook salmon. In 1988, USBR, USFWS, NMFS, and DWR developed a 10-point cooperative program to improve the status of the winter-run in the basin. The two components related to instream flow were raising the Red Bluff Diversion Dam gates to allow fish passage during critical times of the year and improving temperatures by managing Shasta Dam releases. The program also includes correction of pollution problems from Spring Creek, spawning habitat restoration, a reduction in entrainment at water diversions, in-river harvest restrictions, and hatchery studies.

Changes in river management may also happen as a result of instream flow studies by DWR and DFG. These extensive studies address some major instream flow issues, but they only define habitat available for specific life stages of certain fish species and were designed before the winter-run chinook became one of the primary concerns. Much more work is needed to define the flows and reservoir operations that best meet the needs of numerous life stages and species present in the river at any given time.

Lower Yuba River. The Yuba River system drains approximately 1,300 square miles of the western slope of the Sierra Nevada. This area encompasses parts of Sierra, Placer, Yuba, and Nevada counties. Flows in the lower Yuba River are regulated by Englebright Dam and Daguerre Point Dam. There are several diversions by local irrigation districts, mostly in the Daguerre Point Dam area.

Instream flows in the Yuba system are stipulated in a 1965 agreement between Yuba County Water Agency and DFG. Major provisions of the agreement include minimum fish flows below Englebright and Daguerre Point dams and streamflow reduction and fluctuation criteria. These standards have been consistently met and actual flows in the river generally have been higher than the minimum requirements.

The status of existing flow requirements in the lower Yuba River is under review by the SWRCB as part of the Yuba County Water Agency Water Right hearings. These hearings are at the request of DFG and a coalition of angler groups, who filed a complaint in 1988 alleging that the existing instream flow requirements and screening facilities do not adequately protect fishery resources. Several water right issues are also being examined.

A major discussion topic at the hearings is DFG's Lower Yuba River Fisheries Management Plan, which reviews the environmental water needs of the system. The plan proposes a revised flow schedule (summarized in Table 8-3) to optimize habitat for chinook salmon, steelhead trout, and American shad. The plan also includes maximum temperature limits as well as limitations in the amount of daily and long-term fluctuation in flow and water quality. In some months, flows under the proposed new fishery requirements would be at least seven times higher than in the old agreement. Yuba County Water Agency estimates that the flow and temperature revisions would result in water supply deficiencies for urban and agricultural uses of up to 200,000 af, causing cutbacks in water deliveries at least 75 percent of the time. DFG also made recommendations for habitat protection and improvement, new fish screens at existing water diversions, public access for recreation, and additional studies.

The Federal Energy Regulatory Commission, in its February 1993 order issuing the new license for PG&E's Narrows Project, changed the flow requirements to help meet the DFG recommended flows.

Lower Feather River. The Feather River is the largest tributary of the Sacramento River. The three main forks of the Feather River drain into Lake Oroville, where releases into the lower river are controlled by Oroville Dam. Flows below Oroville are also regulated by Thermalito Diversion Dam, located 5 miles downstream of Oroville Dam.

The reach of the river from Oroville to the Sacramento River has one of the largest runs of fall-run chinook salmon in the State, as well as a population of spring-run chinook salmon. The river also has sizable populations of American shad, steelhead, and striped bass during spawning season. In addition, the banks of the lower Feather River support large stands of riparian forest and some of the largest colonies of bank swallows in the State.

Flow levels are presently set by a 1983 agreement between DWR and DFG. The major provisions include minimum flow standards for salmon spawning and rearing between October and March and streamflow reduction limits to prevent salmon redds from drying out. The Department of Fish and Game made recommendations on Feather River flow needs at SWRCB hearings on D-1630 (see Table 8-3). Cooperative DWR/DFG studies are under way to reevaluate the instream flow requirements of the river. The SWRCB required these studies in 1989 to determine whether environmental impacts happen as a result of potential long-term water transfers from Yuba County Water Agency to DWR. The goals are to develop instream flow and water temperature models for the river; to examine the relationship of instream flow to riparian resources, wildlife habitat, and endangered species; and to review the status of recreation and water diversions.

American River. The American River is the first major tributary above the Delta in the Sacramento River system. Flows in the lower river are regulated by Folsom Dam, operated by the USBR. The current flow requirements were set in Decision 893 by the SWRCB in 1958. In 1972, the SWRCB issued Decision 1400 which set higher minimum flows for the lower American River, based on the assumption that Auburn

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Dam would be built. Because Auburn Dam has not been built, these higher flow requirements have never been enforced.

In 1972, the Environmental Defense Fund filed suit against the East Bay Municipal Utility District. EBMUD was proposing to divert its CVP water supply from the American River through the Folsom South Canal, which begins a short distance downstream of Folsom Dam. EDF claimed that diverting the water in the Folsom South Canal violated Article X, Section 2 of the California Constitution, which says that all water should be put to beneficial use to the fullest extent possible. If the water were diverted lower in the system, it could be used for both domestic use and instream use. In 1990, after protracted litigation, Alameda County Superior Court devised a Physical Solution for the lower American River. The Physical Solution allows EBMUD to divert water from Folsom South Canal, but only when flows in the American River are sufficient to protect the fish and wildlife in the river.

The flow requirements in the Physical Solution are not binding on the USBR. The parties to the litigation are conducting additional studies on the flow requirements and expect that the SWRCB will reconsider the issue of minimum flow requirements in the American River after these studies are completed in the next few years.

San Joaquin River Region

The San Joaquin River provides the natural drainage system for the southern half of the Central Valley. Friant Dam, constructed in the 1940s by the USBR, essentially stopped flow in the San Joaquin below the dam, except in extremely wet years. Dams on the tributaries below Friant have also limited flow from the Merced, Tuolumne, Mokelumne, and Stanislaus rivers during most years. The result of water development on the San Joaquin system is that flow in the mainstem below Mendota Pool, near Mendota, consists mainly of agricultural return water and municipal effluent. In recent years, water quality and fisheries releases from New Melones have benefited the Stanislaus River and the mainstem San Joaquin River.

There are several efforts under way to improve conditions for fish and wildlife in the San Joaquin system. The San Joaquin River Management Program, authorized by State legislation (see Chapter 2), is a cooperative undertaking by State, federal, and local agencies to develop actions to provide better flood protection, water quality, fish and wildlife habitat, and recreation. Its fisheries subcommittee has an emergency plan to help the fall-run chinook salmon, which has been at near-record low numbers for the past few years. The plan, which has not been adopted, includes flow pulses from the tributaries during outmigration in April, a barrier at the head of Old River during outmigration to prevent outmigrating smolts from getting diverted into the south Delta, and decreased pumping during April.

Other efforts are underway for improved San Joaquin River management. The USBR has a San Joaquin River management effort which includes fisheries improvements. The DWR Delta pumps mitigation agreement provides funding for projects on the Merced, Tuolumne, and Stanislaus rivers. Finally, DFG and USFWS are conducting instream flow studies on some of the tributaries to help evaluate flow needs.

Tuolumne River. Recently, work was conducted to change the flows in the lower Tuolumne River in the reach below New Don Pedro Reservoir to the confluence of the Tuolumne and San Joaquin rivers. While flows into the lower river are controlled by La Grange Dam, Hetch Hetchy Dam, and New Don Pedro Dam, other upstream water projects, Lake Lloyd (Cherry Valley) and Lake Eleanor, also have a strong influence on operations.

One of the main environmental issues related to instream flow is the severe decline of chinook salmon in the San Joaquin River in general and the Tuolumne River in particular. Present estimates indicate less than 100 fall-run salmon returned to the river during 1991 and less than 200 in 1992, compared to a historical maximum of 130,000 in 1944. Although lower populations of returning salmon can be expected in drought years, especially toward the end of a prolonged drought (for example, 1987–92), increases in populations normally appear as increased natural flow returns which increases habitat and thus future returning salmon populations. Evidence suggests that the overall decline is related to reduced instream flow and Delta diversions. DFG biologists believe that the young salmon survival has been severely reduced by low flows during April and May, which cause unhealthy high temperatures in the Tuolumne River and poor survival during outmigration to the San Joaquin River and the Delta.

As a result of the Phase I Bay–Delta Hearings in 1987, the SWRCB asked that local, State, and federal agencies collaborate on mutually acceptable programs to meet the environmental water needs of California. Probably the most successful product of this request is the 1992 draft agreement among Turlock Irrigation District, Modesto Irrigation District, and DFG to cooperate on long–term instream flow studies. The agreement significantly augments existing instream flow allocations and expands an existing study program designed to fulfill FERC licensing requirements for Don Pedro Reservoir. The proposal to modify flows for fisheries studies is still awaiting approval by FERC.

The new agreement for the Tuolumne River has a complex flow schedule based on ten different water-year types (from Critically Dry to Maximum Wet) and provides flows for spawning, egg incubation, and rearing young in spring and summer. An innovative feature of the plan is the provision for "controlled freshets" (pulse flows) in spring to enhance the migration of young salmon to the Delta. Other parts of the plan include limitations in the hourly fluctuation of flow, restoration of spawning gravel, and juvenile salmon studies.

Mokelumne River. This stream descends from the western slope of the Sierra Nevada into the Sacramento–San Joaquin Delta, where it splits into the north and south forks. Water releases into the lower Mokelumne River are regulated by Camanche Dam; however, the Mokelumne Aqueduct diversion upstream at Pardee Reservoir has an important effect on water availability for instream flow. Flow conditions below the town of Thornton are strongly affected by tidal actions in the Delta.

Flows in the lower Mokelumne River are presently set by a series of temporary agreements between DFG and EBMUD. The system is operated primarily from downstream demands rather than fisheries needs. However, the only long–term agreement provides a water allocation for the Mokelumne River fish hatchery, part of which is returned to the river as instream flow.

EBMUD and DFG entered into a series of one-year MOU's regarding minimum flows for the protection of fisheries during the recent drought while the district was preparing its Lower Mokelumne River Management Plan. However, the district is currently operating voluntarily, consistent with LMRMP, which provides considerably more instream water for the Mokelumne River and the Delta than required by the 1961 agreement with DFG.

An ongoing water quality concern is the leaching of heavy metals from abandoned mines into the river. Historically, high seasonal flows in the system diluted much of the toxic runoff and minimized the impacts, but reduced flows because of Pardee Dam operation cause the heavy metals to accumulate downstream in the sediments of Camanche Reservoir. There have been reports of fish kills from heavy metal pollution and other water quality problems in the lower river.

These and other issues in the basin were reviewed by the SWRCB at water right hearings in 1992 and early 1993. The Mokelumne River Fisheries Management Plan was the basis for DFG's recommendations on higher flow levels, fish attraction, and outmigration flows. The flow recommendations focused on the needs of fall-run chinook salmon and steelhead, but these flows may also benefit up to 25 other species which use the river. A decision by the SWRCB is expected in 1994. In addition, FERC is considering revisions to EBMUD's license. A draft EIS was issued, and a decision by FERC is also expected in 1994.

Merced River. The Merced River is currently the southern limit of the chinook salmon's range along the west coast. Flows in the Merced River are controlled by Merced Irrigation District, which operates the New Exchequer Dam as well as McSwain Dam and Crocker-Huffman Diversion Dam. The current flow requirements are set in part by MID's 1964 FERC license; flow requirements on the license are superseded for the months November 1 through April 1 by the later Davis-Grunsky Agreement between MID and DWR.

The Merced River salmon run has decreased dramatically during the drought in spite of the presence of the Merced River Fish Facility. From a recent high of over 18,000 spawning salmon in 1983, the run has dwindled to fewer than 100 fish during the drought.

A DFG evaluation of flow requirements on the Merced is expected to be complete in about three years. In the interim, DFG, USFWS, and MID are working together to augment flows during critical times for adult salmon upstream migration and downstream migration of juveniles. FERC has required that MID construct delivery facilities and deliver water to the USFWS's Merced Refuge. Until these facilities are constructed, MID has been transferring water for use at other wildlife areas on a schedule to benefit the Merced River chinook salmon run.

Stanislaus River. The flows in the Stanislaus River are essentially controlled by the USBR at New Melones Dam, which began operation in 1981. Flows for the Stanislaus River were set by the SWRCB in D-1422. In addition, a ten-year study of the flow needs of the salmon runs in the Stanislaus River was initiated when New Melones began operations.

This study plan was revised in 1987 and for the interim the minimum water supply for instream use was revised to 98,000 af per year and the maximum was set at 302,100 af per year. Since the revision of the study agreement, additional fisheries studies to determine the instream flow and other habitat needs of chinook salmon have been conducted on the river. Using the study results to date, DFG has developed a set of recommended flows for the Stanislaus River as part of the Stanislaus River Basin and Calaveras River Water Use Program draft EIR/EIS.

The chinook salmon runs in the Stanislaus River have declined during the drought to 150 fish in 1992, down from 12,000 fish in 1984.

San Joaquin River. The mainstem San Joaquin River historically supported a large run of spring chinook salmon. When Friant Dam was constructed in 1942, there were no provisions for instream flow releases to sustain the salmon fishery or maintain a flowing river from Friant to the confluence with the Merced River. This eliminated the salmon run in the upper San Joaquin River. Presently, there is a flowing river immediately downstream of Friant due to releases to satisfy prior water rights holders but no flows are dedicated to fisheries and the river dries up further downstream.

The USBR is preparing an EIS to document the environmental effects of renewing the contracts with customers served by the Friant Unit of the CVP. The CVP Improvement Act also calls for developing a reasonable plan to address fish and wildlife concerns on the San Joaquin River, including re-establishing streamflows below Friant Dam. The plan must be submitted to Congress before it is implemented and the Secretary of the Interior cannot release water for restoration of instream flows from below Gravelly Ford on the San Joaquin River until Congress has authorized the plan.

Eastern Sierra

Three systems, the Owens River, the Mono Basin, and the Truckee River, were selected to typify environmental water use in the eastern Sierra Nevada. In these systems, water diversions that normally flowed to terminus lakes caused adverse impacts to fish and other biological communities. In the first two cases, measures were taken to reduce these diversions to help restore the affected organisms.

Owens River. The Owens River originates in the mountains south of the Mono Basin and historically terminated in Owens Lake. Local irrigators began diverting water from the Owens River before the turn of the century. Most of these local diverters were bought out by Los Angeles Department of Water and Power to firm up its water rights to divert the Owens River into the Los Angeles Aqueduct. This diversion gradually dried up Owens Lake. LADWP began the diversions from the Mono Basin into the Owens River in 1941. It also constructed a series of hydroelectric facilities which dried up a section of the Owens River where it flowed through the Owens River Gorge.

The SWRCB has released a draft EIR for the Mono Basin and downstream areas. The EIR includes studies of the Owens River above Crowley Lake and downstream from Pleasant Valley Reservoir to Tinnemaha, where the aqueduct diverts the Owens River. These studies will allow the SWRCB to evaluate how changes in the Mono Basin diversions could impact the Owens River.

In 1990, the SWRCB amended LADWP's water rights for operation of the hydroelectric projects in the Owens Gorge to require water releases to restore its fishery. LADWP is negotiating with the Mono County District Attorney over the details of the restoration effort. Expectations are that the Owens River Gorge section will soon be restored.

There has been ongoing litigation between Inyo County and LADWP over LADWP's ground water pumping in the Owens Valley. As part of a settlement agreement, an EIR was prepared to discuss environmental impacts of LADWP's water gathering activities in the Owens Valley. As part of this process, there have been discussions about releasing water into the Owens River below the intake for the aqueduct to mitigate impacts discussed in the EIR. However, this issue is still unresolved.

Overall, the Owens River has been the subject of some of the most contentious "water wars" in California. Current proceedings may result in some significant changes in the operations of the Owens River, resulting in restoration of flowing water in some sections that have been dry for over 40 years.

Mono Basin. Mono Lake lies at the center of the Mono Basin, just east of Yosemite National Park at the base of the Sierra Nevada. The lake is one of the oldest in North America and the second largest in California; it is recognized as a valuable scenic, recreational, wildlife, and scientific resource. The area is famous for its distinctive natural features such as tufa towers and spires, structures formed by years of mineral deposition in the lake's saline waters and now visible due to lower lake levels. The lake is a haven for migrating waterfowl. There are two volcanic islands and associated islets in the lake that provide a protected breeding area for large colonies of California gulls and a haven for migrating waterfowl. No fish live in the lake because its water is $2^1/_2$ times saltier than sea water. It supports brine shrimp and brine flies that are major food supplies for California gulls.

The lake receives most of its water from precipitation on its surface and contributions from seven freshwater creeks. However, the lake has no outlet and its salinity has increased over time because of evaporation and stream diversions. All but flood flows from four of the creeks, Lee Vining, Walker, Parker, and Rush, had been diverted to Los Angeles by LADWP. LADWP constructed a fish hatchery to mitigate for the lost fishery. A system of hydroelectric power plants, canals, tunnels, and reservoirs was constructed to generate electricity and carry the water to the Owens Valley where, together with the Owens River diversions, it is transported to Los Angeles via the Los Angeles Aqueduct. Fish populations in the four streams declined as the percentage of water diverted increased.

Diversions from the tributaries accelerated an already declining lake level, resulting in a drop of 45 feet between 1941 and 1982, when the historic low was reached. Studies by the National Academy of Sciences and the University of California have shown that there was a dramatic increase in lake salinity, which may reduce algal blooms, the food supply for the lake's abundant brine shrimp and brine flies. Such a change poses a threat to bird populations in the basin because, as noted, the shrimp and flies are major food resources. The drop in water levels has created a land bridge to one of the lake's two islands, allowing coyotes and other predators to reach important gull rookeries. Large areas of the lake bed have become exposed, causing local air quality problems from dust formed by dried alkali silt.

Disagreements over environmental and water rights issues and their impacts on Mono Lake have resulted in litigation involving these allocations, including a lawsuit filed in 1979 by the National Audubon Society, the Mono Lake Committee, and others. The California Supreme Court in 1983 ruled that, under the public trust doctrine, water rights are subject to review and reallocation by the courts or the SWRCB (a summary of the ruling can be found in Chapter 2). As part of the final settlement in the Audubon and other cases, the courts ordered the SWRCB to determine what instream flows and lake levels are required to protect public trust values. The SWRCB has released an Environmental Impact Report describing the impacts of alternative operational scenarios.

Until the SWRCB reaches a decision, Los Angeles is prohibited by court injunction from diverting streamflow from the tributaries until the lake level stabilizes at 6,377 feet above sea level. Releases of natural flows into four of the lake's tributaries below the diversion dams have been ordered by another court ruling to help reestablish the fishery that existed in the streams prior to diversions.

In September 1989, the Environmental Water Act of 1989 was signed into law. It authorizes DWR to spend up to a total of $60 million from the Environmental Water Fund for water projects or programs that will benefit the environment. A portion of this total was reserved exclusively for projects that would enhance the Mono Lake environment as well as provide replacement water and power to Los Angeles.

Truckee River. Water rights disputes have continued in the interstate Truckee River watershed for more than a century, creating a complex set of issues that influence instream flows in the basin. The river begins at Lake Tahoe and descends the eastern slope of the Sierra Nevada before emptying into Pyramid Lake. Reservoirs that regulate its tributaries include Stampede Reservoir, Martis Creek Reservoir, Boca Reservoir, and Prosser Creek Reservoir. Privately owned, partially controlled lakes or tributaries include Independence Lake and Donner Lake.

Flows in the Truckee River are largely governed by water right decrees and settlements among downstream water users in Nevada. Instream flows in California are largely constrained by these decreed flows. The major water uses are in Nevada, and range from agricultural needs in the Carson Basin and Truckee Meadows to the municipal needs of the rapidly growing Reno/Sparks area, and water required to sustain threatened and endangered fish in Pyramid Lake. Fisheries flows are designated on the tributaries to prevent habitat dewatering; however, new instream flow requirements are being negotiated by California and Nevada as part of the Truckee River Operating Agreement, called for in the Truckee–Carson–Pyramid Lake Water Rights Settlement Act (see Chapter 2). DWR, USFWS, USBR, and several other entities are preparing a joint draft EIR/EIS to address the major issues. Some of the environmental concerns are described below.

Instream flows play a critical role in maintaining threatened, endangered, and game fisheries. Pyramid Lake, Nevada is home to a reintroduced species of Lahontan cutthroat trout, a threatened species, whose native strain was once one of the most prized game fish in the region. Excessive water diversions from the Truckee River and spawning tributaries, and commercial over–harvesting eliminated the species in Pyramid by 1941. Irrigation diversions of most of the Truckee River flows to Pyramid Lake created barriers which blocked spawning areas for the Lahontan cutthroat trout and a native sucker species, the cui–ui. The cui–ui decline, a fish of major cultural importance to the Pyramid Lake Paiute Tribe, led to its listing as an endangered species and legal action to protect the remaining population. Several lawsuits were filed on the operations of Truckee River reservoirs in an attempt to change or maintain project purposes. A lawsuit filed by the Carson–Truckee Water Conservancy District and Sierra Pacific Power Company to overturn the Secretary of Interior's decision to operate Stampede for endangered species did not succeed and the court ruled that the Secretary had a duty to provide water for the cui–ui until such time as it not a listed species. Other litigation is on hold pending negotiation of the Truckee River Operating Agreement, to be signed by both states, the federal government, the Tribe, the Sierra Pacific Power Company, and others. The Operating Agreement, if implemented, will provide additional water and storage for endangered species and municipal and industrial uses, and new instream flow requirements. Existing litigation would then be dismissed or otherwise finally resolved.

Although Lahontan cutthroat trout no longer exist in the upper Truckee River system except for a small population in Independence Lake and its tributary Independence Creek, rainbow and brown trout provide important sport fisheries in the mainstem Truckee River, thus future instream flow agreements will likely take their habitat needs into consideration. DFG and U.S. Forest Service biologists have been conducting fisheries studies since 1986 to help resolve present and possible future conflicts.

Coastal Streams

This section discusses a few of the north and central coast streams which feed into the Pacific Ocean and typify environmental water use for coastal streams. There is also a discussion about the Trinity River, which is a tributary to the Klamath River. A number of other coastal streams have important environmental and regulatory issues. However, their flow levels tend to be relatively small in comparison to other supply and use values presented in the water plan. Flow requirements for many of these locations are discussed in DWR Bulletin 216, *Inventory of Instream Flow Requirements Related to Stream Diversions*, December 1982.

The North Coast region has supported one of the best salmon (chinook and coho) and steelhead fisheries on the West Coast, as well as native-resident trout streams. The coho fishery has decreased in the past decade, coincident with observed declines in most coho stocks along the West Coast. Fish habitat improvement has been under way since 1980 to increase spawning and rearing areas for salmon and steelhead. Biological resources include over 300 species of wildlife and such threatened or endangered species as bald eagles, peregrine falcons, and northern spotted owls.

Klamath River. The Klamath basin (excluding the Trinity River portion) contains over 8 million acres in California and Oregon. Much of the river and its tributaries are included in the State and federal Wild and Scenic Rivers Systems, including the mainstem Klamath below Iron Gate Dam, the mainstem Salmon River, and North Fork Salmon River in California.

Although much of the Klamath River system is classified as wild and scenic, it is far from undisturbed. Stream habitat in the basin has been heavily altered by water diversions, logging, agricultural activities, and mining. For at least 80 years, steelhead, chinook salmon, coho salmon, cutthroat trout, green sturgeon, and other anadromous fish have been blocked from reaching spawning habitat in the river's headwaters above Copco Dam. Habitat degradation has also occurred because flushing flows and fresh spawning gravel are trapped in the reservoirs, causing spawning areas to become armored (paved) with large cobble. These impacts have been partially mitigated by a salmon and steelhead hatchery constructed at Iron Gate, but natural production has diminished greatly in recent years.

Between 1926 and 1960, Copco Dam regulated flow in the Klamath River. The dam operated to meet only power demands, and no minimum flow was required. Extreme, unnatural short-term flow fluctuations resulted in the loss of millions of salmon and steelhead each year. Beginning in 1961, Iron Gate Dam operation improved flows dramatically; however, the instream flow schedule was developed primarily to maintain stocks of fall-run chinook salmon and may not necessarily be suitable for other runs or species. An instream flow study has been started to reevaluate flows below Iron Gate Dam.

Instream flow issues are not limited to the lower Klamath basin. Flow from upper Klamath basin tributaries supports two endangered fish species, the Lost River sucker and the shortnose sucker; these flows also support an important sport fishery for trophy-sized native rainbow trout. The suckers were once a major food source for the Klamath Indian tribe but deteriorating water quality in Upper Klamath Lake and blockage of upstream spawning areas by diversion dams contributed to their severe decline. The U.S. Bureau of Indian Affairs and the U.S. Forest Service are studying instream flow needs of the tributaries to determine what improvements can be made for environmental water needs.

Trinity River. The Trinity River basin encompasses a watershed of almost 3,000 square miles in Trinity and Humboldt counties. It has been altered substantially by dams, road construction, water export, logging, mining, and other land-use practices. The Trinity River Division of the CVP was completed in 1963, leading to reduced streamflows, sedimentation, and vegetation encroachment in the Trinity River, which has adversely impacted the fisheries.

Originally, releases from the Trinity and Lewiston dams to the Trinity River were approximately 120,000 af per year. In the late 1970s, the USBR increased the releases to vary between 270,000 and 340,000 af per year. In 1991, the Secretary of the Interior responded to a request for increased flows from the Hoopa Valley and Yurok tribes and increased the minimum flows to 340,000 af per year. The tribes rely on the harvest of salmonids for subsistence and ceremonial and commercial needs.

A major USFWS study is under way to establish the optimum flow schedule for fisheries on the Trinity River. Initial study results indicate that 340,000 af per year may provide enough water to maintain 80 percent of the existing habitat for salmon populations. Tentative recommendations include providing 2,000 cfs in spring for rearing and short-term "flushing" flows to aid young salmon outmigration. The CVP Improvement Act of 1992 requires a permanent annual allocation of 340,000 af from Lewiston Reservoir for fishery needs.

The CVP diverts Trinity River flows into the Sacramento River system for use in the Central Valley. Increased instream flows in the Trinity River will reduce the amount of water available in the Central Valley.

Smith River. The Smith River is the only major watershed in California that is undammed and relatively undeveloped, making it a unique and pristine resource. The basin, which includes the South Fork, Middle Fork, North Fork, Siskiyou Fork, and mainstem of the Smith River, has the highest runoff per square mile in the State.

The Smith River was included in the California Wild and Scenic River system in 1972, and was later included in the federal Wild and Scenic River system in 1981. To provide more protection, 305,000 acres of the basin were declared a National Recreation Area in 1990 and a part of the Six Rivers National Forest. A USFS Management Plan was prepared to direct recreation, fisheries, forestry, fire control, habitat restoration, and other activities for the region.

Lagunitas Creek. Lagunitas Creek is a good illustration of the difficulty in satisfying competing water demands in a small, coastal watershed. The system is one of the major watercourses in Marin County, draining from the northern slopes of Mount Tamalpais to Tomales Bay.

Marin Municipal Water District is the largest user of Lagunitas Creek water and operates Lagunitas, Bon Tempe, Kent, and Alpine reservoirs on the main stream and Nicasio Reservoir on a tributary. The system provides basic water supplies to approximately 170,000 people in Marin County. Lagunitas Creek is also used by North Marin Water District, which serves approximately 1,000 to 1,500 residents in the Point Reyes Station area. Municipal demand is expected to increase as a result of continuing population growth. There are also two substantial agricultural users, one of whom operates Giacomini Dam at the mouth of the creek.

Lagunitas Creek once supported large numbers of coho salmon and steelhead trout, but populations have been significantly reduced by inadequate instream flows, prolonged drought, and habitat loss. The coho decline may also be related to other factors in that this species has declined in most streams along the West Coast of the United States. Another notable resource is the endangered California freshwater shrimp. Fresh water outflow from the creek also plays a significant role in the maintenance of the Tomales Bay Estuary.

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The environmental needs of the system were recognized by the SWRCB in 1982, when a minimum flow of 1 cfs was established at the Giacomini Dam fish ladder. However, recent drought conditions and rapid population growth have made it clear that there is significant potential for demand to habitually exceed the available supply. In 1990, MMWD, DFG, and several other concerned parties requested new SWRCB hearings to resolve these conflicts. Hearings were held in spring 1992; the SWRCB heard testimony on the instream flow and water quality needs for fisheries, freshwater requirements of Tomales Bay, and the present and anticipated future status of agricultural and municipal water needs.

Carmel River. Historically, the Carmel River and its tributaries were a major spawning ground and nursery stream for steelhead rainbow trout, with approximately 2,000 to 3,000 spawners per year. Construction of San Clemente and Los Padres dams, surface diversions, and ground water pumping along the river substantially changed flow patterns of the Carmel River which led to fish passage problems, delayed migration, reduced rearing habitat, and mortality during emigration. Although the last count in 1984 indicated a total run of 860 adults, the current drought combined with diversions has limited or prevented migration since 1987.

Flow releases from San Clemente Dam are negotiated annually, but generally remain at 5 cfs. There is also an agreement between dam operators and DFG to provide at least 5 cfs below Los Padres Dam. In spite of the presence of releases from the two dams, the lower Carmel River is dry in summer and fall during normal rainfall years and sometimes year-round in drought years. In contrast, studies indicate that at least 40-75 cfs are needed from January through March to allow spawners to pass through critical riffles. Additional flow is necessary during other months in upstream areas for incubation, migration, and rearing.

A number of projects have been proposed by Monterey Peninsula Water Management District to increase the water supply in the basin and to enhance instream flow. A Draft Environmental Impact Report/Statement has been prepared which identifies enlargement of Los Padres Dam (to 16,000 af or 24,000 af) and development of a desalination plant as the preferred alternative. Some spawning and rearing habitat would be lost with the enlargement; however, instream flows and water temperatures would improve, particularly in the lower Carmel River.

San Luis Obispo Creek. San Luis Obispo Creek extends from San Luis Obispo Bay, across the San Luis Obispo basin and up into the Santa Lucia Range. There are no water projects on the creek, but the flow is reduced by small-scale stream diversions and ground water pumping. Natural runoff sustains year-round flow in the upper watershed of the stream; however, in the dry months of the year the streamflow below San Luis Obispo is often exclusively from wastewater discharge.

At present, the major issue for this system is a proposal to reclaim wastewater for irrigation and industrial users, thereby reducing instream flow in the lower reach of the stream. Treated wastewater currently supports an important riparian corridor, providing habitat for game and nongame species. Species of special concern include the southwestern pond turtle and red-legged frog. Although fisheries resources in the lower reach of the creek appear to be limited because of poor water quality, the stream is a migration corridor for one of the most southerly races of steelhead trout. Migration of steelhead occurs during the wettest months of the year, when instream flow is enhanced throughout the system. Resident-strain, nonmigratory rainbow trout also occur in the stream. An instream flow study has been completed for the reach below the wastewater treatment plant and an Environmental Impact Report is being prepared for the reclamation project.

Santa Ynez River. The Santa Ynez River system historically supported the largest run of steelhead trout in Southern California. However, much of the main channel is now of poor quality or unsuitable for spawning and rearing due to low or nonexistent flows, high temperatures, passage barriers, and habitat degradation. A self-sustaining population of trout remains in one of the tributaries, Salsipuedes Creek, but numbers are low. Rearing habitat is especially limited in the creek and it appears that run size depends on the magnitude of winter storms.

The river is regulated in its upper reaches by Juncal Dam and Gibralter Dam and downstream by Bradbury Dam and Lake Cachuma. There is presently no instream flow requirement for the river; Lake Cachuma is operated to fill the lower ground water basin and to protect downstream water users. Some information is available about the possible effect of different levels of instream flow from studies associated with the proposed enlargement of Lake Cachuma. Analyses show that if water quality is satisfactory and flows are constant, releases of 50 to 120 cfs are needed to provide optimal habitat between Bradbury Dam and Buellton. Maintaining flows in the reach between the ocean and the confluence with Salsipuedes Creek appears to be particularly important to allow steelhead to reach the highest-quality spawning habitat. Lower flows of from 6 to 50 cfs may also be beneficial if combined with habitat improvement.

Existing Environmental Instream Flow Requirements

Environmental instream flow requirements were compiled by reviewing existing fishery agreements, water rights, court decisions, and congressional directives. These flows are included in Table 8-4. The instream applied water for a major river is based on the largest fish flow specified in an entire reach of that river or, for wild and scenic rivers, the flow is based on unimpaired natural flow. Instream applied water for fisheries within a hydrologic region is determined by adding all the fishery flow needs of the major rivers within that region. Instream net water needs for any river are the portion of the applied water which flows throughout the river or is the flow leaving the region. Total instream net water needs of a region are computed by adding instream net water needs of all the major streams within the region. Depletion of instream water needs is the portion of environmental instream flows that flow to a salt sink or the ocean. Figure 8-5 shows examples of applied water, net water, and depletion for instream fishery flow.

The North Coast wild and scenic river flows were determined by estimating average and drought-year natural runoff of the portion of the streams designated as wild and scenic. These streams include the Smith, Klamath, Trinity, and Eel rivers. In the Central Valley and other areas with wild and scenic rivers, instream flows are extensively reused downstream of the designated reaches.

Existing environmental instream flow requirements will increase from the 1990 level by about 600,000 af by 2020. Future environmental instream needs reflect recent increases in Trinity River flows (required by the CVPIA), an increase in the Yuba River fishery flow (required by a recent FERC action), and increased Delta carriage water requirements (due to increased future exports under SWRCB D-1485). Further, the CVPIA reallocates 800,000 af for Central Valley fishery needs along with 200,000 af for wildlife refuge water needs. The long-term disposition of these supplies is the subject of a program EIS now being developed by the USBR. A proactive approach to identifying fishery needs—such as a better temperature control for spawning conditions, better screening of diversions to reduce incidental take, and better timing of reservoir

Table 8-4. Instream Environmental Water Needs by Hydrologic Region

(thousands of acre-feet)

Hydrologic Region	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
North Coast								
Applied water demand[1]	18,850	8,950	18,973	9,073	18,973	9,073	18,973	9,073
Net water demand[1]	18,850	8,950	18,973	9,073	18,973	9,073	18,973	9,073
Depletion[1]	18,850	8,950	18,973	9,073	18,973	9,073	18,973	9,073
San Francisco Bay								
Applied water demand	4,615	3,085	4,615	3,085	4,615	3,085	4,615	3,085
Net water demand	4,615	3,085	4,615	3,085	4,615	3,085	4,615	3,085
Depletion	4,615	3,085	4,615	3,085	4,615	3,085	4,615	3,085
Central Coast								
Applied water demand	4	2	4	2	4	2	4	2
Net water demand	1	0	1	0	1	0	1	0
Depletion	1	0	1	0	1	0	1	0
South Coast								
Applied water demand	0	0	0	0	0	0	0	0
Net water demand	0	0	0	0	0	0	0	0
Depletion	0	0	0	0	0	0	0	0
Sacramento River								
Applied water demand	3,443	3,009	3,488	3,009	3,488	3,009	3,488	3,009
Net water demand	3,323	2,905	3,323	2,905	3,323	2,905	3,323	2,905
Depletion	0	0	0	0	0	0	0	0
San Joaquin River								
Applied water demand	331	243	331	243	331	243	331	243
Net water demand	331	243	331	243	331	243	331	243
Depletion	0	0	0	0	0	0	0	0
Tulare Lake								
Applied water demand	41	41	68	68	68	68	68	68
Net water demand	34	34	56	56	56	56	56	56
Depletion	34	34	56	56	56	56	56	56
North Lahontan								
Applied water demand	0	0	0	0	0	0	0	0
Net water demand	0	0	0	0	0	0	0	0
Depletion	0	0	0	0	0	0	0	0
South Lahontan								
Applied water demand	128	122	128	122	128	122	128	122
Net water demand	128	122	128	122	128	122	128	122
Depletion	73	67	73	67	73	67	73	67
Colorado River								
Applied water demand	0	0	0	0	0	0	0	0
Net water demand	0	0	0	0	0	0	0	0
Depletion	0	0	0	0	0	0	0	0
TOTAL								
Applied water demand	27,400	15,500	27,600	15,600	27,600	15,600	27,600	15,600
Net water demand	27,300	15,300	27,400	15,500	27,400	15,500	27,400	15,500
Depletion	23,600	12,100	23,700	12,300	23,700	12,300	23,700	12,300

(1) Includes 17.8 MAF and 7.9 MAF flows for North Coast Wild and Scenic Rivers for average and drought years, respectively.

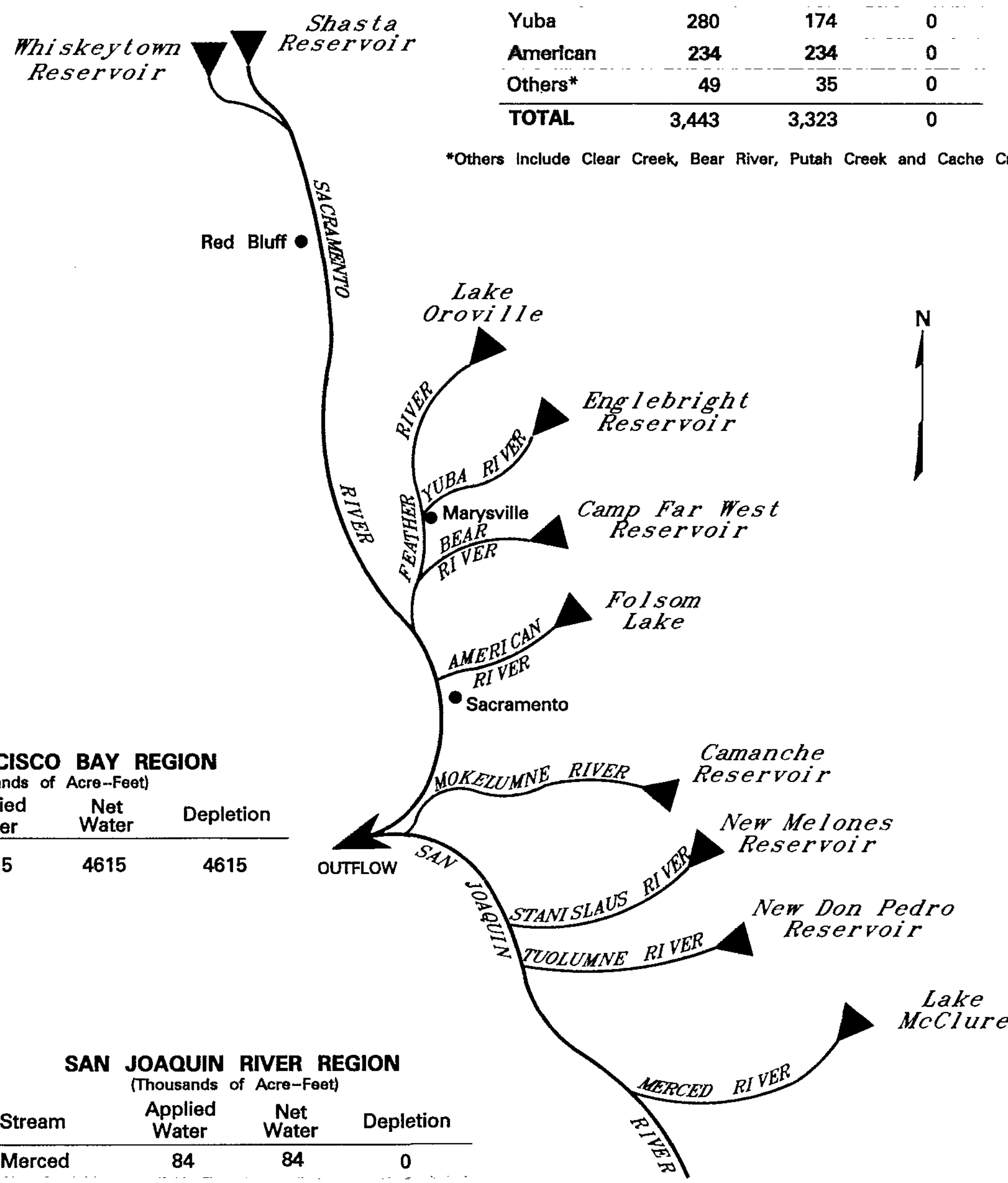
Figure 8-5. Examples of Applied Water, Net Water Use, and Depletion for Instream Fishery Flows

Example of Central Valley Streams—1990 Average Year

SACRAMENTO RIVER REGION
(Thousands of Acre-Feet)

Stream	Applied Water	Net Water	Depletion
Sacramento	1,903	1,903	0
Feather	977	977	0
Yuba	280	174	0
American	234	234	0
Others*	49	35	0
TOTAL	3,443	3,323	0

*Others include Clear Creek, Bear River, Putah Creek and Cache Creek



SAN FRANCISCO BAY REGION
(Thousands of Acre-Feet)

Stream	Applied Water	Net Water	Depletion
D1485 Outflow	4615	4615	4615

SAN JOAQUIN RIVER REGION
(Thousands of Acre-Feet)

Stream	Applied Water	Net Water	Depletion
Merced	84	84	0
Tuolumne	123	123	0
Stanislaus	110	110	0
Mokelumne	14	14	0
TOTAL	331	331	0

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releases to improve fishery habitat, among others—must be taken so that solutions to the Delta problems mesh with actions taken for improving fishery conditions. To that end, many of the actions identified in the CVPIA for cost sharing with the State will improve conditions for aquatic species.

In the short-term, environmental water needs are uncertain, but improved, as a number of actions by regulatory agencies are under way to protect aquatic species. The outcome of some of those actions depends on solutions to the complex problems in the Delta.

Wetlands

During the past 15 years, actions taken by State and federal governments demonstrate an increased awareness of both the broad public benefits of wetlands and the need to protect and enhance wetland habitats. One such recent action was the "no net loss of wetlands" policy adopted by both federal and state governments; California's wetland policy states "no net loss in the short-term and an increase in wetlands in the long-term." Protecting and restoring wetlands will cause additional demands on California's water supplies since a critical need for many of the existing and potential public and private wetlands is a reliable and affordable supply of good quality water. Figure 8-6 shows publicly managed fresh-water wetlands.

Wetlands are transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is often covered by shallow water during some parts of the year. Wetlands can be categorized according to specific habitat and type of vegetation. In general, wetlands are divided into:

- Saltwater and brackish water marshes, which are usually located in coastal areas;
- Freshwater wetlands, which are primarily in the inland areas of California; and
- Freshwater forested and scrub wetlands, which are commonly referred to as riparian habitat.

Historically, wetland habitat was often seen as only a breeding ground for disease-carrying mosquitos. Federal, State, and local policies to drain, fill, or somehow convert wetlands to more "productive" uses was the norm. For example, the federal Swamp Land Acts of the 1800s gave 65 million acres of wetlands to 15 states, including California, for reclamation. As recently as the 1960s and 1970s, the federal Agricultural Stabilization and Conservation Service (ASCS) promoted drainage of wetlands through cost-sharing programs with farmers.

As a result of these and other activities, many of California's wetlands were converted to agricultural and urban uses, and water that had naturally flooded the wetlands was diverted for other needs. Estimates of wetlands that historically existed in California range from 3 to 5 million acres. The current estimate of wetland acreage in California is approximately 450,000 acres; this represents an 85 to 90 percent reduction—the greatest percentage loss in the nation.

Wetlands are now seen as very important ecosystems with the following multiple values and functions:

- ***Biological Diversity.*** Wetlands provide important habitat for diverse communities of plants and animals, including over 50 percent of the federally listed threatened or endangered species.
- ***Waterfowl Habitat.*** Wetlands provide the principal habitat for migratory waterfowl. California provides critical wintering habitat for millions of waterfowl migrating along the Pacific Flyway, which extends from Canada to Mexico.

Figure 8-6. Publicly Managed Fresh-Water Wetlands

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- **Fisheries.** Wetlands provide direct spawning and rearing habitats and food supply that supports both freshwater and marine fisheries.
- **Flood Control.** Wetlands detain flood flows, reducing the size and destructiveness of floods.
- **Water Quality.** Wetlands absorb and filter pollutants that could otherwise degrade ground water or the water quality of rivers, lakes, and estuaries.
- **Ground Water Recharge.** Some wetlands recharge aquifers that provide urban and agricultural water supplies.
- **Recreation.** Wetlands support a multi-million-dollar fishing, hunting, and outdoor recreation industry nationwide.

Gray Lodge Wildlife Area is a managed wetland area near Gridley, California. The Butte and Sutter basins contain large areas of wetlands that serve as critical habitat for migratory waterfowl in the Pacific Flyway.

Five areas of California contain the largest remaining wetlands acreage in the State. These areas are in the Humboldt Bay, San Francisco Bay, Suisun Marsh, Klamath Basin, and Central Valley. Humboldt and San Francisco bays both contain tidal and nontidal salt and brackish marshes as well as large areas of reclaimed farmland and other diked historic tideland that offers important bird habitat in the winter. The brackish wetlands in Suisun Marsh are the largest contiguous estuarine marsh in the lower 48 states. This area consists of approximately 52,000 acres, or 12 percent of the State's total wetlands acreage. Along the coast, river mouths and estuaries contain predominantly smaller wetlands with the exception of a few major remaining coastal wetlands such as Elkhorn Slough in Monterey County, and Tijuana Estuary and San Diego Bay in San Diego County. Most wetlands in the Klamath Basin and the Central Valley are artificially managed because the natural flooding pattern no longer exists. These artificially managed wetlands are under either public or private ownership and are maintained by intentional flooding and water level manipulation.

Wetlands receive water from several sources including ground water, local surface water, imported surface water from the CVP, the SWP, and local projects, as well as agricultural return flows. Until recently, most of California's managed wetlands did not have dependable water supplies; this will change for 15 refuges in the Central Valley with the passage of the CVP Improvement Act of 1992. (See Chapter 2 for a summary of this act.) The wetland provisions of this Act are discussed in more detail below. In most cases, both public and private wetlands receive water through informal arrangements. The availability of water for wetlands was reduced in the 1980s for several reasons. The biggest reasons were the 1987-92 drought and water quality problems, such as selenium-contaminated agricultural return flows. Agricultural conservation practices have reduced the amount of good-quality agricultural return flows available downstream for wetlands.

Several laws and programs were recently adopted by federal, State, regional, and private agencies and organizations to protect and restore wetlands in California. These laws and programs are intended to protect existing wetlands, improve wetland management practices, and increase wetland habitat. In many cases these laws and programs could result in increased water demands for wetlands. Several of the major wetland laws and programs are discussed below.

Federal Wetland Policies and Programs

A number of actions by federal agencies and federal legislation will have an important effect on wetlands and wetland management in California.

National Wetlands Policy Forum. This forum was convened in 1987, at the request of the U.S. Environmental Protection Agency, by the Conservation Foundation. Its purpose was to address major policy concerns about how the nation should protect and manage its wetlands resources. In November 1988, the Forum released its final report, *Protecting America's Wetlands: An Action Agenda.*

The first element of the forum's recommended program was to establish a national wetlands goal that would improve the consistency among the nation's wetland policies and programs. The forum recommended "an interim goal to achieve no overall net loss of the nation's remaining wetlands base and a long-term goal to increase the quantity and quality of the nation's wetlands resource base."

USBR Refuge Water Supply Report. The USBR is the lead agency in a multi-agency study evaluating the water supplies for refuges in the Central Valley. In 1989, the USBR completed the first phase of the study and prepared the *Report on Refuge Water Supply Investigations*, which evaluates the water and power needs, surface water delivery systems, ground water availability, recreation and wildlife resources, and habitat management objectives for 15 refuges in the Central Valley. The 15 refuges include 10 National Wildlife Refuges, 4 State Wildlife Areas, and the Grasslands Resource Conservation District, covering a privately owned wetland area.

For each of the 15 areas, the report quantifies the water needs into four levels:

Level 1—Existing firm water supply (95,163 af per year)

Level 2—Current average annual water deliveries (381,550 af per year)

Level 3—Supply for full use of existing development (493,050 af per year)

Level 4—Supply for optimum habitat management (526,200 af per year)

Central Valley Project Improvement Act of 1992 (PL 102-575). This act was signed by the president in October 1992. Title 34, Section 3406 (d) requires the Secretary of the Interior to provide firm water supplies to various wildlife refuges and habitat areas in the Central Valley, either directly or through contractual agreements with other parties. Specifically, water is to go to 15 existing wildlife refuges identified in the USBR Refuge Water Supply Report and to the 5 habitat areas identified in the USBR/DFG San Joaquin Basin Action Plan/Kesterson Mitigation Plan.

The act directs the Secretary of the Interior to immediately provide firm water supplies at "Level 2" for the 15 Central Valley refuges, or 381,550 af per year. By 2002, the Secretary is required to increase the water deliveries for the 15 refuges to "Level 4," or 526,200 af per year. This is an increase of 144,650 af per year over the Level 2 water supply and about 200,000 af over the 1990 water supply of these refuges.

For the 5 habitat areas listed in the San Joaquin Basin Action Plan/Kesterson Mitigation Plan, the Act requires the Secretary to immediately provide two-thirds of the water supply needed for full habitat development. The total amount needed for full habitat development must be provided by the year 2002. The SJBAP calculates that approximately 63,200 af per year will be needed for full habitat development of the five areas. This amount, however, does not include transportation losses which the USBR estimates at approximately 21 percent, or 13,600 af. Total water supply would amount to about 76,800 af per year if transportation losses were included.

California Wetland Policies and Programs

Recent policies and laws adopted by the Governor and the legislature underscore the importance of protecting and restoring California's wetlands. The following discussion briefly outlines several of the most significant State wetland policies.

California Wetlands Conservation Policy. In August 1993, the Governor announced the "California Wetlands Conservation Policy." The goals of the policy are to establish a framework and strategy that will:

- Ensure no overall net loss and achieve a long-term net gain in the quantity, quality, and permanence of wetlands acreage and values in California in a manner that fosters creativity, stewardship, and respect for private property.
- Reduce procedural complexity in the administration of State and federal wetlands conservation programs.
- Encourage partnerships to make landowner incentive programs and cooperative planning efforts the primary focus of wetlands conservation and restoration.

The Governor also signed Executive Order W-59-93, which incorporates the goals and objectives contained in the new policy and directs the Resources Agency to establish an Interagency Task Force to direct and coordinate administration and implementation of the policy.

The State's wetland acreage is expected to increase as a result of the Governor's new policy. The policy recommends the completion of a statewide inventory of existing wetlands that will then lead to the establishment of a formal wetland acreage goal. The Resources Agency expects that the wetland acreage and quality could increase by as much as 30 to 50 percent by the year 2010. Based on the current estimate that there are 450,000 acres of existing wetlands in the State, the increase could be as much as 225,000 acres.

Central Valley Habitat Joint Venture and North American Waterfowl Management Plan. In 1986, the North American Waterfowl Management Plan was signed by the United States and Canada. The NAWMP provides a broad framework for waterfowl management in North America through the year 2000; it also includes recommendations for wetland and upland habitat protection, restoration, and enhancement.

Implementing the NAWMP is the responsibility of designated joint ventures, in which agencies and private organizations collectively pool their resources to solve waterfowl habitat problems. The plan focuses on seven habitat areas; the Central Valley of California is one of those areas.

The Central Valley Habitat Joint Venture was established in 1988 to "protect, maintain, and restore habitat to increase waterfowl populations to desired levels in the Central Valley of California consistent with other objectives of the NAWMP."

To achieve this goal, the CVHJV adopted six objectives for the Central Valley: (1) protect 80,000 acres of existing wetlands through fee acquisition or conservation easement; (2) restore 120,000 acres of former wetlands; (3) enhance 291,555 acres of existing wetlands; (4) enhance water habitat on 443,000 acres of private agricultural land; and (5) secure 402,450 af of water for 15 existing refuges in the Central Valley. The CVHJV derived their estimates of water needs for existing refuges from the USBR's 1989 refuge water supply study. In August 1993, DWR became an ex-officio member of the CVHJV Management Board.

Suisun Marsh Plan of Protection. The Suisun Marsh, in southern Solano County, is the largest wetland in the State. In 1974, the California Legislature recognized the threat of urbanization and enacted the Suisun Marsh Preservation Act (SB 1981), requiring that a protection plan be developed for the Marsh.

In 1978, the SWRCB issued D-1485, setting water salinity standards for Suisun Marsh from October through May to preserve the area as a brackish-water tidal marsh and to provide optimum waterfowl food plant production. D-1485 placed operational conditions on the water right permits of the federal CVP and the SWP. Order 7 of the decision requires the permittees to develop and fully implement a plan, in cooperation with other agencies, to ensure that the channel salinity standards are met.

In 1984, DWR published the *Plan of Protection for the Suisun Marsh Including Environmental Impact Report.* DWR, DFG, the Suisun Resource Conservation District and the USBR prepared this report in response to D-1485. The USFWS also provided significant input. The Plan of Protection proposes staged implementation of several activities such as monitoring, a wetlands management program for marsh landowners, physical facilities, and supplemental releases of water from CVP and SWP reservoirs. The Suisun Marsh Preservation Agreement entered into among the four agencies has also been authorized by an Act of Congress in PL 99-546. To date, $66 million has been spent on studies and facility construction.

Inland Wetlands Conservation Program. In 1990, the Legislature passed legislation authorizing the Inland Wetlands Conservation Program within the Wildlife Conservation Board. This program carries out some of the Central Valley Habitat Joint Venture objectives by administering a $2-million-per-year program to acquire, improve, buy, sell, or lease wetland habitat.

Wetland Water Supply and Demands

State and federal officials estimate that there are approximately 450,000 acres of wetlands (excluding flooded agricultural lands) in California. This is only a rough estimate because a comprehensive inventory of California's wetlands has not been made. The Resources Agency is planning to conduct an inventory of the states' wetlands and to track changes in acreage and habitat types. This information about acreages and habitat types is needed to accurately quantify the water needs for wetlands.

Currently, the best available data about wetland habitat and acreage in California are for managed wetlands. Consequently, the scope of this report is an assessment of the managed wetland water needs. Managed wetlands consist of either freshwater and nontidal brackish water wetlands or agricultural lands flooded to create wildlife habitat. These lands are maintained by the intentional flooding and manipulation of water levels. Although agricultural lands flooded for wildlife habitat are not considered to be wetlands, the term "wetlands" used in the following section refers to both natural wetlands and flooded agricultural lands. All agricultural lands flooded for wildlife are considered managed wetlands and the majority of California's natural wetlands are managed wetlands. Of the estimated 450,000 acres of natural wetlands in the State, approximately 75 percent (335,000 acres) are managed.

Managed wetlands are owned and operated as State and federal refuges, private wetland preserves owned by nonprofit organizations, or private duck clubs. Agricultural lands flooded to create waterfowl habitat are mostly rice fields in the Sacramento Valley and corn or other small grain crops in the Delta. The flooded agricultural lands in California provide very important winter feeding habitat for many migratory waterfowl.

A brief description of the wetland habitat and water needs for each hydrologic basin is provided in this section. Table 8-5 summarizes the 1990 and projected wetland water needs statewide for each hydrologic region. Eight of the ten hydrologic basins have managed wetland habitat with freshwater needs. No managed wetlands with freshwater needs were identified in the Central Coast or South Lahontan regions.

North Coast Region. In the North Coast region the managed wetlands include federal and state wildlife refuges, most of which are in the Klamath Basin area. No privately managed wetlands were identified in this region. The total flooded acreage is approximately 54,000 acres, about 60 per cent (33,000 acres) of which are seasonal wetlands. The water source for these wetlands is surface water, including agricultural drainage water.

San Francisco Region. The Suisun Marsh is the only identified managed wetland in the San Francisco Region. The marsh consists of approximately 55,000 acres of managed wetlands. The State owns about 10,000 acres and 44,000 acres are under private ownership and managed as duck clubs. The water source for these wetlands is surface water. The freshwater needs for the Suisun Marsh were based on the D-1485 salinity standards adopted by the SWRCB. The SWP and the CVP are required to release up to 145,000 af annually in critical years to maintain the standards. No supplemental freshwater is provided during average years.

Sacramento River Region. This region contains the largest wetland acreage in the State, approximately 175,000 acres of wetlands. The majority of these wetlands are under private ownership, mostly as duck clubs in the Butte, Colusa, and American basins and the Delta. The Central Valley Habitat Joint Venture Implementation Plan estimates the current area of privately owned wetlands at approximately 90,000 acres. Water for these wetlands is from several sources including CVP supplies, agricultural return flows, and ground water.

Agricultural field crops, such as rice, corn, and grain, provide habitat for a variety of wildlife species. Rice fields augment natural wetlands and refuges with valuable wintering habitat for migratory waterfowl in the Sacramento Valley. Rice growers in the Sacramento Valley, in cooperation with the Nature Conservancy, Ducks Unlimited, and the California Waterfowl Association, initiated a partnership plan to experiment with ways to decompose rice straw while enhancing waterfowl habitat. Under this plan, rice fields are flooded from November through February, providing wetland habitat for migratory birds while decomposing rice straw. The effects on water supply and fish need further study.

San Joaquin Region. Approximately 110,000 acres of managed wetlands are in the San Joaquin region. Almost 82 percent of these wetlands (90,000 acres) are under private ownership in the Grasslands area. Water supplies for these wetlands were historically less dependable than in other regions, especially for the private wetlands. In past years, a major source of water for most of the wetlands was agricultural drainage water. However, with the discovery of selenium contamination, this water source was significantly reduced. The water supplies for this region will significantly increase and be more reliable due to the provisions of the CVP Improvement Act of 1992. By 2002,

Table 8-5. Wetlands Water Needs by Hydrologic Region
(thousands of acre-feet)

Hydrologic Region	1990 average	1990 drought	2000 average	2000 drought	2010 average	2010 drought	2020 average	2020 drought
North Coast								
Applied water demand	349	349	353	353	353	353	353	353
Net water demand	237	237	239	239	239	239	239	239
Depletion	235	235	237	237	237	237	237	237
San Francisco Bay								
Applied water demand	160	160	160	160	160	160	160	160
Net water demand	160	160	160	160	160	160	160	160
Depletion	160	160	160	160	160	160	160	160
Central Coast								
Applied water demand	0	0	0	0	0	0	0	0
Net water demand	0	0	0	0	0	0	0	0
Depletion	0	0	0	0	0	0	0	0
South Coast								
Applied water demand	2	2	6	6	6	6	6	6
Net water demand	2	2	6	6	6	6	6	6
Depletion	2	2	6	6	6	6	6	6
Sacramento River								
Applied water demand	484	484	629	629	629	629	629	629
Net water demand	394	394	537	537	537	537	537	538
Depletion	168	168	207	207	207	207	207	208
San Joaquin River								
Applied water demand	268	268	413	413	413	413	413	413
Net water demand	223	223	339	339	339	339	339	339
Depletion	190	190	306	306	306	306	306	306
Tulare Lake								
Applied water demand	41	41	68	68	68	68	68	68
Net water demand	0	0	0	0	0	0	0	0
Depletion	0	0	0	0	0	0	0	0
North Lahontan								
Applied water demand	17	17	17	17	17	17	17	17
Net water demand	17	17	17	17	17	17	17	17
Depletion	17	17	17	17	17	17	17	17
South Lahontan								
Applied water demand	0	0	0	0	0	0	0	0
Net water demand	0	0	0	0	0	0	0	0
Depletion	0	0	0	0	0	0	0	0
Colorado River								
Applied water demand	39	39	44	44	44	44	44	44
Net water demand	39	39	44	44	44	44	44	44
Depletion	39	39	44	44	44	44	44	44
TOTAL								
Applied water demand	1,400	1,400	1,700	1,700	1,700	1,700	1,700	1,700
Net water demand	1,100	1,100	1,300	1,300	1,300	1,300	1,300	1,300
Depletion	800	800	1,000	1,000	1,000	1,000	1,000	1,000

there will be approximately 150,000 af of additional water supplied to the public refuges and the Grasslands Resource Conservation District.

North Lahontan Region. Two public wetlands were identified in this region: Honey Lake Wildlife Area and Willow Creek Wildlife Area. Together, the total acreage is approximately 10,600 acres, of which half or about 5,500 acres are flooded wetlands. The Truckee–Carson–Pyramid Lake Settlement Act includes authority for purchases of water to restore and maintain wetlands in the Lahontan Valley in Nevada.

Tulare Lake Region. The Tulare Lake Basin is the driest basin in the Central Valley. Historically, it contained the largest single block of wetland habitat in California, approximately 500,000 acres. Water from the Sierra Nevada drained into a series of shallow lake basins which in most years formed a sink. Currently there are only about 6,400 acres of flooded wetland habitat in the basin. The acreage should increase within ten years as water supplies increase as required by the CVP Improvement Act of 1992. By 2020, there will be approximately 20,000 af of additional water supplied to the two public refuges in this basin, Kern NWR and Pixley NWR.

Colorado River Region. Managed wetlands in the Colorado region are primarily around the Salton Sea and along the Colorado River. These wetlands receive freshwater from the Imperial Irrigation District, not salt water from the Salton Sea. There are approximately 3,500 acres of flooded wetland habitat in this region.

Future Water Needs for Wetlands

This report includes the estimated future water needs for existing wetlands, wetlands that have been recently acquired, and the water supply increases required by the CVP Improvement Act of 1992. A corresponding rise in wetland water use is likely to follow implementation of State and federal policies to increase wetland acreage. Most newly acquired wetlands will include the water rights associated with the property; in these situations there consequently would be a transfer of water from one use, most likely agricultural, to wetlands. Increases in wetland acreage are based on available acquisition and restoration funding as well as private incentive programs.

One goal established for the Central Valley by the Central Valley Habitat Joint Venture is to restore 120,000 acres of former wetlands. Another goal stated by the Resources Agency is an increase of 30 to 50 percent by 2010. This could be an increase of approximately 225,000 acres statewide. Enhancing existing wetlands could also result in an increase in water needs for wetlands. The CVHJV goal for the Central Valley is to enhance 291,555 acres of existing wetlands.

Although the exact acreage that will be either acquired or enhanced is unknown, water needs for wetlands will increase as California begins to restore and protect the State's historic wetlands.

Summary of California's Environmental Water Needs

Analyses of environmental water needs are based on (1) instream fishery flow needs; (2) wild and scenic river flows; (3) water needs of fresh-water wetlands (and Suisun Marsh); and (4) Bay–Delta requirements, including operations, water quality objectives, and outflow. Environmental water needs are computed using similar procedures for calculating applied water, net water, and depletion as those for agricultural and urban water demand. Table 8-6 summarizes the environmental water needs for each hydrologic region, as computed in the previous sections for the Bay–Delta, environmental instream flows, and water needs for wetlands.

Table 8-6. Environmental Water Needs by Hydrologic Region
(thousands of acre-feet)

Hydrologic Region	1990		2000		2010		2020	
	average	drought	average	drought	average	drought	average	drought
North Coast								
Applied water demand[1]	19,199	9,299	19,326	9,426	19,326	9,426	19,326	9,426
Net water demand[1]	19,087	9,187	19,212	9,312	19,212	9,312	19,212	9,312
Depletion[1]	19,085	9,185	19,210	9,310	19,210	9,310	19,210	9,310
San Francisco Bay								
Applied water demand	4,775	3,245	4,775	3,245	4,775	3,245	4,775	3,245
Net water demand	4,775	3,245	4,775	3,245	4,775	3,245	4,775	3,245
Depletion	4,775	3,245	4,775	3,245	4,775	3,245	4,775	3,245
Central Coast								
Applied water demand	4	2	4	2	4	2	4	2
Net water demand	1	0	1	0	1	0	1	0
Depletion	1	0	1	0	1	0	1	0
South Coast								
Applied water demand	2	2	6	6	6	6	6	6
Net water demand	2	2	6	6	6	6	6	6
Depletion	2	2	6	6	6	6	6	6
Sacramento River								
Applied water demand	3,927	3,493	4,117	3,638	4,117	3,638	4,117	3,638
Net water demand	3,717	3,299	3,860	3,442	3,860	3,442	3,860	3,443
Depletion	168	168	207	207	207	207	207	208
San Joaquin River								
Applied water demand	599	511	744	656	744	656	744	656
Net water demand	554	466	670	582	670	582	670	582
Depletion	190	190	306	306	306	306	306	306
Tulare Lake								
Applied water demand	82	82	136	136	136	136	136	136
Net water demand	34	34	56	56	56	56	56	56
Depletion	34	34	56	56	56	56	56	56
North Lahontan								
Applied water demand	17	17	17	17	17	17	17	17
Net water demand	17	17	17	17	17	17	17	17
Depletion	17	17	17	17	17	17	17	17
South Lahontan								
Applied water demand	128	122	128	122	128	122	128	122
Net water demand	128	122	128	122	128	122	128	122
Depletion	73	67	73	67	73	67	73	67
Colorado River								
Applied water demand	39	39	44	44	44	44	44	44
Net water demand	39	39	44	44	44	44	44	44
Depletion	39	39	44	44	44	44	44	44
TOTAL								
Applied water demand	28,800	16,800	29,300	17,300	29,300	17,300	29,300	17,300
Net water demand	28,400	16,400	28,800	16,800	28,800	16,800	28,800	16,800
Depletion	24,400	12,900	24,700	13,300	24,700	13,300	24,700	13,300

(1) Includes 17.8 MAF and 7.9 MAF flows for North Coast Wild and Scenic Rivers for average and drought years, respectively.

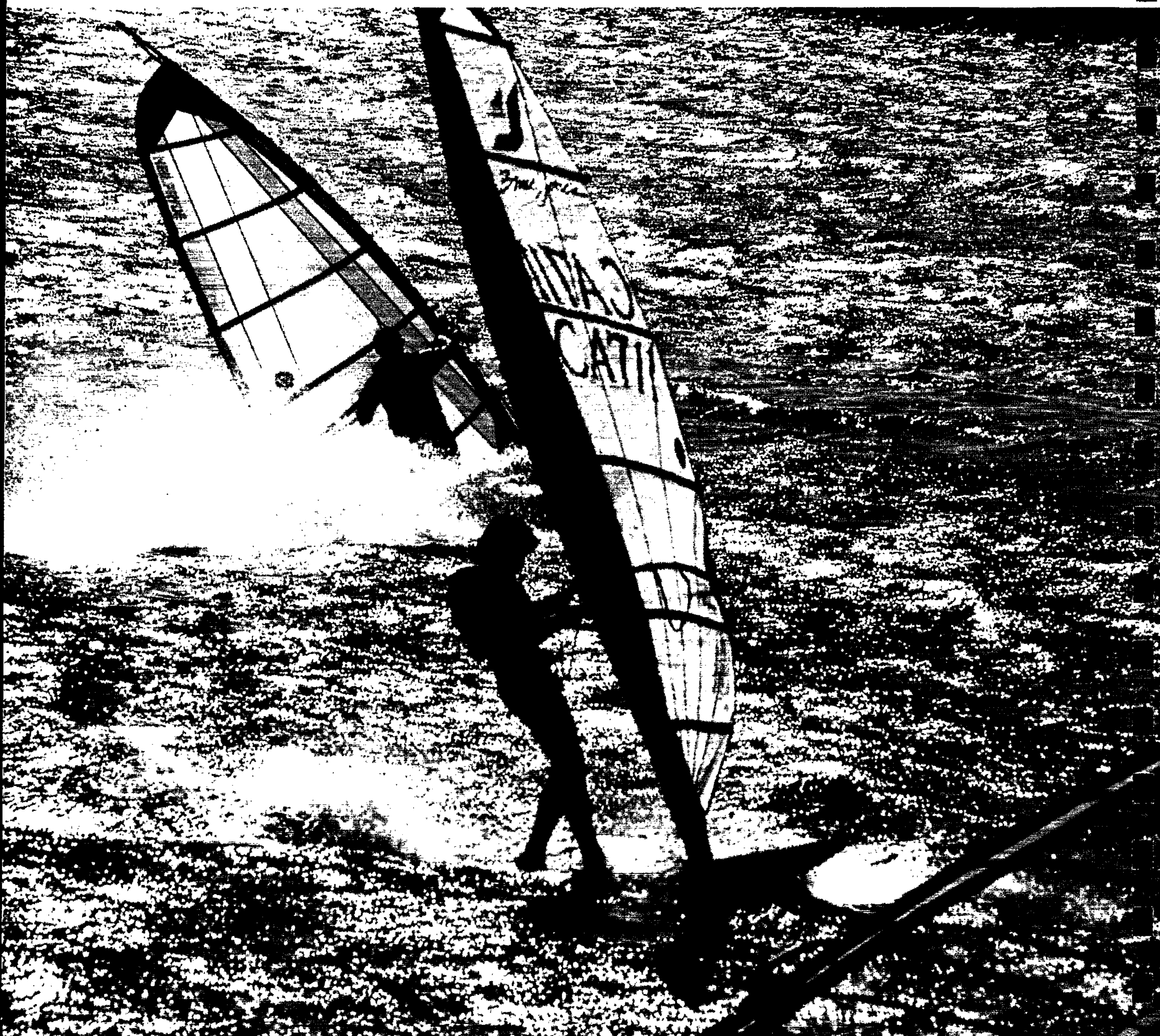
Recommendations

1. Current methodologies for identifying cause and effect relationships for habitat and fishery populations need to be improved and new techniques developed and implemented by the State to better define goals and assess environmental water use.

2. DWR Bulletin 216, *Inventory Of Instream Flow Requirements Related to Stream Diversions*, was last updated in 1982. An up-to-date inventory of flow requirements should be completed and maintained.

3. Water resources management for protection of fish and wildlife species should be planned and performed under a multi-species approach.

Wind surfers at Lake Perris. California's many lakes, reservoirs, bays, and rivers offer plenty of opportunities for recreation. Wind surfing is popular at many lakes and reservoirs in the inland areas.



Chapter 9

Water-Based Recreation

Lakes and rivers have always been a primary focus for outdoor recreation activities. A few decades ago, recreation occurred incidentally at natural water bodies, streams, and rivers. The abundance of potential recreation sites limited the need for careful planning of recreation facility development. The situation began to change after World War II, when a rapidly growing population that was increasingly affluent sought the great outdoors to escape the congestion of growing urban areas.

Water-based recreation has become an integral part of meeting society's recreational needs. Recreation at reservoirs, natural lakes, and streams must be managed to prevent overuse and degradation. Public water supply projects, such as the State Water Project, have helped to provide additional recreational opportunities for Californians. In some cases, reservoir releases can contribute to downstream recreation benefits by improving fisheries or by creating white-water rafting opportunities that would not be possible in the absence of reservoir regulation. Often, however, there are conflicting values and needs for the same river system.

This chapter describes water-based recreation and State recreation facilities constructed specifically to enhance such recreation and water use for recreation. It also discusses some of the inherent conflicts between the natural setting and the built environment relating to water-based recreation.

Recreation and Water Management

Reservoir Recreation

Although California is not usually associated with the phrase "land of 10,000 lakes," there are thousands of lakes and reservoirs within the State's borders. Many of these lakes occur naturally, but over 1,400 are created by artificial impoundments. While reservoirs are often synonymous with recreational opportunity, diverse recreational opportunities are usually incidental to, and compete with, a reservoir's primary purposes. Nevertheless, recreation planning and development is usually an element of public water development design. At State Water Project reservoirs, recreation is always considered along with other project purposes, as required by the Davis-Dolwig Act.

Swimming, fishing, and boating are popular activities at California's reservoirs. Recreation facilities such as beaches, boat ramps, docks, trails, restrooms, and access roads add to the quality and safety of the recreation experience. Often, picnic and camping facilities are also developed to meet public demand. The way reservoir water levels are managed and operated directly affects the quality and economic value of recreational and other contingent activities.

Reservoir operations for water supply are usually adequate to support established recreation activities, particularly when surface runoff from precipitation is near normal. Changes in operations, because of drought or demand exceeding supply, have reduced both available recreational opportunities and per capita benefits and will continue to do so. In general, reservoir recreation benefits decrease as receding water levels reduce water surface areas, make boat ramps less accessible, and leave recreation facilities farther from shorelines. On the other hand, decreased recreation benefits at drawn-down reservoirs may be offset to some extent by increases in stream recreation benefits.

The California Fish and Game Code requires maintenance of stream habitat below dams, and in some cases, even artificially created instream resources, but recently the requirements for sensitive species preservation have become more critical. For example, increased releases from Shasta Reservoir to control temperature will benefit salmon habitat on the Sacramento River, but also will reduce recreational opportunities within the Shasta Lake area. On the other hand, minimum storage recommendations at Shasta, invoked for sensitive species protection, also could ultimately benefit recreation in the river downstream of Shasta Dam. A table summarizing minimum instream flow requirements at selected sites is presented in Chapter 8, *Environmental Water Use* (Table 8-3).

Hydroelectric generating facilities can have varying impacts on both reservoir and river recreation depending on whether the operation is direct release or pumped storage and whether releases are constant or subject to peaking. As with water supply releases, increased stream flows from power generation provide recreation benefits that to some degree offset the effects of diminished reservoir storage.

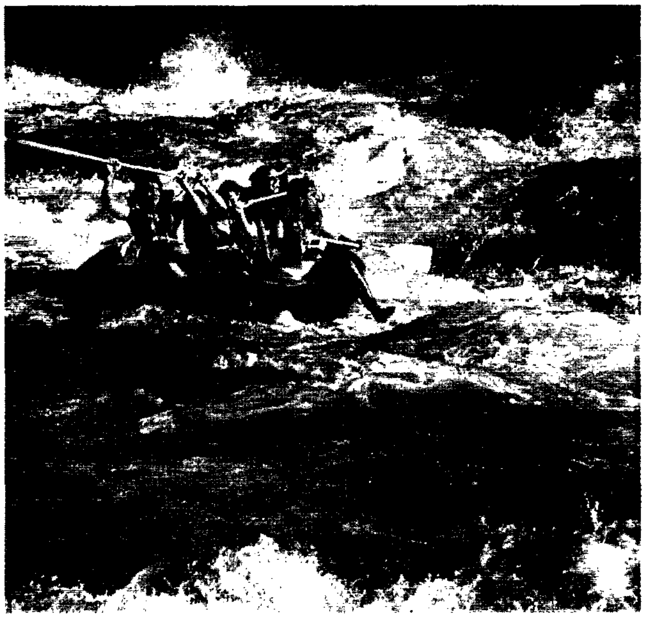
A pumped storage operation can create additional recreation opportunities at forebay and afterbay reservoirs if water levels do not fluctuate too greatly on a daily basis. As the recent drought reduced the attractiveness of large reservoirs like Lake Oroville and San Luis Reservoir, Thermalito Afterbay and O'Neill Forebay, respectively, supported increased recreation use; this raised the need to add temporary facilities to augment facilities previously adequate at these sites.

Shifts in use, as those described above, can create potential water quality problems. Water quality and human health and safety can be jeopardized if recreation becomes too intense at any one site. Algal blooms and high coliform counts are not uncommon when swimming areas become overcrowded. Pollution by petroleum products and other chemicals is inevitable when motorized equipment, such as boats and jet skis, operate on the water. The risk of worsening water quality underscores the importance of proper recreation planning as outdoor recreation continues to grow in popularity and competition for existing water supplies intensifies.

River Recreation

Riverine environments can offer types of recreation not available from the large water surface impoundments, although in many cases similar recreation facilities are developed to meet public demand. In addition to fishing and swimming, some of the recreation opportunities associated with rivers and streams are white-water sports such as rafting, kayaking, and canoeing. Also, the Sacramento-San Joaquin Delta provides exceptional recreational opportunities for houseboating as well as striped bass, catfish, and sturgeon fishing, among others. Water needs for these activities are incidental to environmental water use and are included in Chapter 8.

Many streams are unimpaired by water development facilities, such as many of those listed under the federal or State Wild and Scenic Rivers Acts. These streams offer seasonal recreational opportunities in natural settings. (For a summary of the Wild and Scenic Rivers Acts, see Chapter 2.) Most of the wild and scenic rivers are in northern California and include all or parts of the Smith, Trinity, Klamath, Van Duzen, Eel, Feather, American, and Tuolumne rivers. Maps showing regional wild and scenic rivers are in Volume II.



Rugged natural beauty and some of the most renowned fishing streams in North America attract over 10 million people annually to the North Coast Region. A national park and over 40 State beaches, parks, and recreation areas are in the region.

Other streams, such as those controlled by reservoir releases, offer opportunities to enhance downstream flows that can benefit recreation values. Streams that would naturally run only intermittent-tently, for example, can have year-round flows following reservoir construction and operation. This kind of conversion can develop new fisheries, add to recreational-area attractiveness, and enhance wildlife habitat. Regulation of larger streams and rivers can support white-water sports for a longer season or increase the diversity of available activities.

In some cases a hydropower development can completely change river recreation benefits. For example, peak releases from the North Fork Stanislaus River project greatly increased white-water rafting but reduced opportunities for swimming in the summer. Local agencies are continuing to study the impacts and benefits of this conversion.

The use and economic benefits provided by river recreation can be substantial, although difficult to estimate because such use occurs over diffuse areas and is often not under the jurisdiction of one area or operator. Table 9-1 lists minimum flow levels for rafting at 12 major California rivers popular with rafters and kayakers. Rafting and boating conditions forecast for these and other popular California rivers are published each spring in the DWR pamphlet *Water Supply Outlook for Boaters*, although few data are available on recreation use over long reaches of these waters. Estimated rafting use on these rivers was compiled in a 1983 report by the Planning and Conservation League. It must be emphasized that optimum flows ordinarily occur only for a short period during a year, and popular areas with prolonged periods suitable for rafting often result from coordination with release schedules for hydroelectric generation from major dams and reservoirs.

Wildland Recreation

Many designated wildlife refuges in California owe their existence to imported water which supports large populations of migratory waterfowl. Seasonal wetland habitat at such refuges is integral to maintenance of waterfowl populations along the Pacific Flyway. Further discussion of water at wildlife refuges can be found in Chapter 8. Historically, recreation values associated with such wildlife have focused primarily on hunting. More recently, DFG has cited birding (bird watching) as the fastest-growing recreation activity in the nation.

Table 9-1. Recreation Use and Minimum Rafting Flows on Some Popular California Rivers

Stream	*Minimum Rafting Flow (cfs)*	*Annual Rafting Use (visitor days)*	*Comments*
South Fork American River	1,200	100,000	Depends on Chili Bar Dam releases
Lower American River	1,500	460,000	Below Nimbus Dam
East Fork Carson River	400	7,000	Often low in summer
Kern River	450	20,000	Below Lake Isabella
Kings River	800	18,000	Below Pine Flat Reservoir
Klamath River	1,300 +	15,000	Below Iron Gate Dam
Merced River	500	14,000	Often low in summer
Russian River	350-650	100,000	Often low in summer
Sacramento River	5,000	125,000	Flow usually higher
Smith River	600	7,000	Limited in summer
Trinity River	550 +	33,000	Lewiston Reservoir releases
Truckee River	250	106,000	Too low without Tahoe outflow
Tuolumne River	800	6,000	Above New Don Pedro

In 1988, the California Wildlands Program became law. Broadly supported and lauded by many, the program directed DFG to provide and charge for nonconsumptive refuge-based recreation. Although the program has not met projected targets for pass sales, visitation at refuges is significant. Prior to the program's inception, DFG records for its larger wildlife areas indicated that nonconsumptive use by individuals and groups averaged more than 260,000 visitor days annually, 15 percent higher than use attributed to hunters and anglers. In 1993 DFG, in cooperation with USBR, monitored visitation and recreation at several of its management areas in order to collect more accurate and recent visitor data.

Water-based Recreation Policy and Planning Responsibility

Recreation planning is a relatively new component of water project development. In the past, recreation facilities were often added as afterthoughts to existing projects as the public demand increased. Many water planning and development agencies were among the first to recommend that recreation be treated as a water project purpose along with flood control, urban water supply, irrigation, hydroelectric generation, and other traditional purposes in the planning and financing of new projects. Today's water supply management and development must balance conflicting needs and values for environmental, recreational, and other water supply benefits.

Conflicts which arise between maintaining optimum recreational opportunities through minimally fluctuating reservoirs versus stream flows for healthy fisheries, or in some cases even greater flows for rafting, must be evaluated. Both the State and federal legislative bodies enacted laws requiring that recreation be a part of their respective water projects, and today recreation planning is an important part of any Environmental Impact Report or Statement.

The Davis–Dolwig Act

The Davis–Dolwig Act was passed by the State Legislature in 1961. It is the primary statement of State policy concerning recreation and fish and wildlife enhancement at State-constructed water facilities. The act sets fundamental policies and establishes the responsibilities of the State departments that participate in the program.

The Davis-Dolwig Act declares that recreation and fish and wildlife enhancement are among the purposes of State water projects. It specifies that costs incurred for these purposes shall not be included in the prices, rates, and charges for water and power to urban and agricultural users. It also provides for DWR to allocate to recreation and fish and wildlife enhancement a portion of the costs of any facility of the SWP. Under Davis-Dolwig, acquiring real property for recreation and fish and wildlife enhancement must be planned and initiated concurrently with and as part of the land acquisition program for other project purposes. Reimbursement for land acquisition has in the past been from State oil and gas revenues, while facilities have been constructed with general fund and bond financing.

Three State departments are assigned specific responsibilities under the act. DWR is responsible for planning recreation and fish and wildlife enhancement and preservation measures in connection with State-constructed water projects. DWR is also responsible for acquiring any needed lands. The Department of Parks and Recreation is responsible for design, construction, operation, and maintenance of the actual recreation features at these sites. DPR must consider arrangements in which federal or local agencies could become participants, if appropriate. The Department of Fish and Game is responsible for managing the fish and wildlife resources at State water projects. A later amendment to the act authorized the Wildlife Conservation Board to design and construct fishing access sites along SWP aqueducts.

Federal Water Project Recreation Act

The Federal Water Project Recreation Act, comparable to the Davis-Dolwig Act, was enacted in 1965 and affects federal water development projects. It requires those federal agencies approving water projects to include recreation development, including provisions for cost and benefit allocation, as a condition of issuing permits. Consideration of recreational development must be made in conjunction with any navigation, flood control, reclamation, hydroelectric, or multi-purpose water resource project. For example, a Federal Energy Regulatory Commission license to operate a hydroelectric facility usually includes an obligation to construct specific recreation facilities to provide for anticipated demand.

Periodic relicensing and FERC review can result in revised project operation and impacts on fishing, white-water boating, and other established activities and facilities. The issues of relicensing typically focus on water quality and environmental water needs; however, it is important to recognize the secondary effects of revised operation on recreation.

It should be noted that terms of Federal Power Act licenses supersede state regulation of projects in most cases. There have been instances where holders of FPA licenses have claimed exemption from state safety of dams requirements, minimum streamflow requirements, state Wild and Scenic River designation, and condemnation of easements and lands for projects in state parks, see Chapter 2.

Trends in Recreation Area Use

DPR statistics show a steady increase in visits to State park and recreation areas. Visitation has grown at a rate even faster than that of California's population. Increased leisure time, economical transportation, and changing demographics contribute to the demand for recreational facilities. The best estimates are that over 60 million visits are made to State park system units each year, indicating growth of roughly 15 percent per year throughout most of the 1980s; however, this growth rate has slowed somewhat in the last few years.

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Although increased recreation area fees may be partly to blame, and the latest recession may have curbed discretionary income expenditures for recreation, the recent six-year drought is commonly cited as the primary reason that the trend of increased recreational use has diminished at many reservoirs. San Luis Reservoir was subject to severe drawdown during the drought, although O'Neill Forebay was maintained relatively full, and the level of Los Banos Reservoir only dropped a few feet.

Trout fishing near Kyburz, California. Cold water releases from upstream reservoirs help maintain flow and temperatures that benefit downstream fisheries.

Perhaps another index of drought impacts to water-based recreation is evidenced by declining California sport fishing license sales. Sales were down over a quarter-million (13 percent) during the recent drought. Although a pre-existing trend of decline may be attributable to changing demographics, and large price increases for licenses, there can be little argument that drought impacted outdoor recreation.

Water Use for Recreation

Recreational activity and resources generally do not consume significant amounts of water, no more than 3 percent of the statewide total. Although some water developments were designed and constructed primarily to provide recreation, most recreational facility developments are on streams, lakes, or reservoirs operated for other purposes. In some cases, minimum reservoir releases may be imposed on the latter to maintain recreation activities below a dam, or the drawdown of a reservoir may be limited during the recreational season. Consumptive use occurs when water allocated specifically for recreation with no other benefit is not recaptured downstream or is evaporated from a larger-than-normal water surface area. The amount of water consumed through reservoir operations is usually very small compared to other consumptive uses; reservoir operations also benefit fish, wildlife, and other environmental values.

Water for drinking and sanitation is also a factor at every recreation site. Landscaping adds appreciably to overall water use at these sites; however, consumption associated with recreational development is still exceedingly small when compared to urban, agricultural, and other uses.

A planning standard for intensely used recreation areas is 50 gallons of water per person per day. Many dispersed day-use activities consume less than 10 gallons of water per visitor day. DPR reports that per capita daily visitor use averages 10 to 14 gallons throughout the diverse State Park System. Recreation facilities provided by federal, State, and local governments support about 1 billion recreation days in California per year. Therefore, using the DPR average and the average recreation day use, annual recreational-related water consumption at public facilities is probably less than 50,000 acre-feet. In 1978, the California State Park System (over 200 park units) used approximately 750 million gallons (550 million for domestic uses, and 200 million gallons for irrigation purposes). Distributed statewide, this small amount of water can be considered part of water developed for other uses (urban recreation, fish and wildlife enhancement, etc.). The water used by private recreation developments is typically included in urban water needs.

The recent drought events have encouraged accelerated installation of low-flow shower heads, low-flow toilets, and other water-saving devices throughout the State park system and at many other recreation areas. Since 1978 DPR has endeavored to implement water-saving measures throughout the State park system. These measures include: (1) restricted hours of shower use; (2) flow restrictors for showers; (3) spring-loaded or self-closing faucets; (4) low-volume flush toilets; (5) inserts in toilet tanks to reduce use of water; (6) replacing water-using restrooms with chemical toilets; (7) increased efficiency of all water systems by correcting leaks and improving intake structures and storage facilities; (8) providing information to park visitors on water shortages; (9) stressing water conservation in interpretive programs; and (10) reduced watering for landscaped areas. Combined, all of these measures have resulted in about a 30-percent reduction in water use per State park visitor since 1978.

Water Project Operations and Recreation Benefits

The recreation opportunities provided by reservoirs generate enormous benefits to California's economy. In 1985, an estimated $500 million was spent on water-related activities in the Delta and at major reservoirs. The estimated 7 million visitors to the Sacramento-San Joaquin Delta generated an estimated $125 million; the 6.6 million visitors to the 12 SWP reservoirs and the California Aqueduct brought in an estimated $170 million; and benefits of the 11.6 million visitors to 10 of the 22 CVP reservoirs totaled $208 million. In addition to the half-billion dollars detailed above, a similar amount was probably spent at the many local and regional reservoirs and streams, statewide.

The kinds of recreational facilities and activities found at any developed water recreation site are usually similar, regardless of whether the site was developed by a local, federal, or State agency. Given this similarity, this report focuses on the water recreation at SWP facilities to give the reader an in-depth look at water-based recreation connected with water supply development.

State Water Project Recreation

One of the project purposes of the SWP is recreation, which takes several forms at various facilities. Recreation at SWP facilities includes camping, boating, fishing, swimming, bicycling, and other activities. Recreation facilities were incorporated into SWP facilities from the upper Feather River reservoirs in Plumas County to Lake Perris in Riverside County. More than 6 million recreation days of use were generated by SWP facilities during 1990.

As designed, the SWP includes the physical and operational capacity to deliver up to 45,500 acre-feet of water annually for recreation uses. About half of this amount was developed specifically for recreation-related uses. SWP water allocation exclusively for recreational use will be done on a case-by-case basis for future projects and for operational revisions.

State Water Project Reservoirs. SWP recreation facilities, from north to south, are at Antelope Lake, Lake Davis, Frenchman Lake, Lake Oroville, Lake Del Valle, Bethany Reservoir, San Luis Reservoir, O'Neill Forebay, Los Banos Reservoir, Pyramid

Lake, Castaic Lake, Silverwood Lake, and Lake Perris. A brief description of each area follows. Estimated current annual and cumulative attendance at each facility, from facility construction through 1990, is presented in Table 9-2.

Antelope Lake and Dam are in Plumas National Forest on Upper Indian Creek, tributary to the North Fork Feather River. The reservoir is approximately 43 miles from Quincy and was created in 1964 to help meet the increasing demand for water–oriented recreation, improve fishing in Indian Creek, and assure a constant, year–round flow of water below the dam. Antelope Lake Recreation Area is operated by the U.S. Forest Service. Recreational opportunities include: camping, fishing, picnicking, water–skiing, swimming, boating, hunting, hiking, and winter sports such as snowmobiling. Total visitor use between 1965 and 1990 was 3,617,000.

Lake Davis and Grizzly Valley Dam are in the Plumas National Forest on Big Grizzly Creek. The lake is 8 miles north of Portola, on a tributary of the Middle Fork Feather River. Lake Davis was created in 1967 to provide recreation, to improve fish habitat in Big Grizzly Creek, and to contribute to domestic water supply. Lake Davis recreation facilities are operated by the U.S. Forest Service and offer camping, fishing, picnicking, boating, hunting, hiking, and winter sports such as cross–country skiing and snowmobiling. Total visitor use between 1968 and 1990 was 6,836,000.

Frenchman Lake and Dam also are within the Plumas National Forest on Little Last Chance Creek, a tributary of the Middle Fork Feather River. The lake is about 30 miles northwest of Reno, Nevada and 15 miles northeast of Portola. Frenchman Lake was created in 1961 to provide recreation and develop irrigation water for Sierra Valley. Frenchman Lake Recreation Area is operated by the U.S. Forest Service and offers camping, fishing, picnicking, water–skiing, swimming, boating, hunting, hiking, and winter sports such as cross–country skiing and snowmobiling. Total visitor use between 1962 and 1990 was 7,051,000.

Lake Oroville and Oroville Dam are in the foothills of the Sierra Nevada above the Central Valley. The dam is 1 mile downstream of the confluence of the Feather River's three major tributaries. Lake Oroville is 5 miles east of Oroville and about 75 miles north of Sacramento. Completed in 1967, Lake Oroville is part of a multipurpose proj-

Table 9-2. Estimated Current Annual and Cumulative Attendance (through 1990) at State Water Project Reservoirs

Facility	*Cumulative Total Visitation*	*Current Annual Use*
Antelope Lake	3,617,000	300,000
Lake Davis	6,836,000	300,000
Frenchman Reservoir	7,051,000	300,000
Lake Oroville*	14,377,000	750,000
Lake Del Valle	6,793,000	475,000
Bethany Reservoir	586,000	85,000
San Luis/O'Neill Complex	11,785,000	700,000
Los Banos Reservoir	1,119,000	100,000
Pyramid Lake	4,950,000	350,000
Castaic Lake	18,821,000	1,000,000
Silverwood Lake	10,150,000	750,000
Lake Perris	23,354,000	1,500,000

* Including wildlife area

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ect that includes water storage, power generation, flood control, recreation, and fish and wildlife enhancement. Lake Oroville State Recreation Area is operated by DPR and offers camping, picnicking, horseback riding, hiking, sail and power boating, water skiing, fishing, swimming, and boat-in camping. Limited waterfowl hunting is permitted only on Thermalito Afterbay. Total visitor use between 1968 and 1990 was 14,377,000. This figure includes visitation at Oroville Wildlife Area beginning in 1980.

Lake Del Valle and Del Valle Dam are located in Arroyo Del Valle, just south of Livermore Valley, about 11 miles from Livermore. Lake Del Valle was created in 1968 to provide recreation and fish and wildlife enhancement, flood control for Alameda Creek, and regulatory storage for the South Bay Aqueduct. Lake Del Valle facilities are operated by East Bay Regional Park District and offer camping, picnicking, horseback riding, swimming, hiking, wind surfing, boating, and fishing. Total visitor use between 1970 and 1990 was 6,793,000.

Bethany Reservoir is located 1 1/2 miles down the California Aqueduct from Harvey O. Banks Delta Pumping Plant, about 10 miles northwest of Tracy, in Alameda County. Bethany Reservoir was completed in 1967, and serves as a forebay for South Bay Pumping Plant and a conveyance facility in this reach of the California Aqueduct. Bethany Reservoir facilities are operated by DPR and offer picnicking, fishing, boating, wind-surfing, hiking, and bicycling. Total visitor use between 1978 and 1990 was 586,000.

San Luis Reservoir and Dam are located on San Luis Creek in the foothills on the west side of the San Joaquin Valley in Merced County, 12 miles west of the city of Los Banos. San Luis Reservoir is part of the San Luis Joint-Use Facilities, which serve SWP and the federal CVP. It was completed in 1967 and provides storage for water diverted from the Sacramento-San Joaquin Delta for later delivery to the San Joaquin Valley and Southern California. San Luis Reservoir State Recreation Area is operated by DPR. There are extensive recreational developments and three wildlife areas around the reservoir and at O'Neill Forebay which offer camping, picnicking, sail and power boating, water-skiing, wind surfing, fishing, swimming, hiking, bicycling, and waterfowl hunting. Total visitor use of San Luis Reservoir and O'Neill Forebay from 1967 through 1990 was 11,785,000.

Los Banos Reservoir and Detention Dam are on Los Banos Creek, about 7 miles southwest of the City of Los Banos. The dam provides flood protection for San Luis Canal, Delta-Mendota Canal, City of Los Banos, and other downstream developments. Los Banos Reservoir offers camping, picnicking, fishing, swimming, and hiking. Total visitor use of Los Banos Reservoir from 1973 to 1990 was 1,119,000.

Pyramid Lake and Dam are within the Angeles and Los Padres National Forests, on Piru Creek about 14 miles north of the town of Castaic. Pyramid was completed in 1973 and is a multipurpose facility that provides regulatory storage for Castaic Power Plant, normal regulatory storage for water deliveries from the SWP's West Branch, emergency storage in the event of a shut-down of the SWP to the north, recreational opportunities, and incidental flood protection. Pyramid Lake facilities are operated by the U.S. Forest Service and offer camping, picnicking, boating, water-skiing, fishing, and swimming. Total visitor use from 1974 to 1990 was 4,950,000.

Castaic Lake and Dam are at the confluence of Castaic Creek and Elizabeth Lake Canyon Creek, 45 highway miles northwest of Los Angeles and about 2 miles north of the community of Castaic. Castaic was completed in 1972 to act as a regulatory storage facility for water deliveries, to provide emergency storage, and to furnish recreational development and fish and wildlife enhancement. Castaic Lagoon, downstream of the dam, provides a recreation pool with a constant water surface elevation of 1,134 feet and also functions as a recharge basin for the downstream ground water basin. The lagoon provides an additional 3 miles of shoreline and 197 surface acres. Castaic Lake State Recreation Area is operated by Los Angeles County Department of Parks and Recreation and offers fishing, boating, water-skiing, sailing, picnicking, and swimming. Total visitor use from 1972 to 1990 was 18,821,000.

Silverwood Lake and Cedar Springs Dam are within San Bernardino National Forest, on the West Fork Mojave River, about 30 highway miles north of the city of San Bernardino. It is a multipurpose project that was completed in 1971, and is a regulating facility and water source for agencies serving the surrounding mountain and desert areas. There are 2,400 acres of recreation land surrounding Silverwood Lake. The Silverwood Lake State Recreation Area is operated by DPR and offers camping, picnicking, boating, water-skiing, fishing, swimming, bicycling, and hiking. Total visitor use from 1972 to 1990 was 10,150,000.

Lake Perris and Perris Dam, the terminal storage facility of the SWP, are in northwestern Riverside County, about 13 miles southeast of the city of Riverside and 5 miles northeast of the town of Perris. The reservoir was completed in 1974 and is a multipurpose facility providing water supply, recreation, and fish and wildlife enhancement. Lake Perris State Recreation Area is operated by DPR and offers camping, picnicking, horseback riding, sail and power boating, water-skiing, fishing, swimming, hiking, bicycling, hunting, and rock climbing. A marina and water slide are operated by a concessionaire. Total visitor use from 1974 to 1990 was 23,354,000.

Future SWP recreational facilities are tied closely to future projects. The Los Banos Grandes Facilities could provide an estimated 465,000 recreation days at the Los Banos Grandes Reservoir, if constructed.

California Aqueduct Recreation. DWR's focus in developing recreation along the California Aqueduct includes bicycling, fishing, and aqueduct safety. The California Aqueduct Bikeway is on the paved service roads along the canal facilities of the SWP. Two sections of bikeway have been developed, one in the San Joaquin Valley and the other in Southern California.

The San Joaquin Valley section extends 67 miles down the west side of the valley, from Bethany Reservoir (west of Tracy) to the San Luis Reservoir State Recreation Area (west of Los Banos). This section of the bikeway has been designated a National Recreation Trail by the Secretary of the Interior.

The Southern California section extends 107 miles through the Antelope Valley, from Quail Lake to a point 2 miles north of Silverwood Lake in the San Bernardino National Forest. The Southern California section is closed at this time because of aqueduct enlargement construction. Several reaches will be reopened after all work on the enlargement is completed and some safety improvements have been made.

Fishing is permitted in canal reaches along nearly 400 miles of the California Aqueduct, beginning at Bethany Reservoir (west of Tracy) and extending to just north of Silverwood Lake. In addition, 17 fishing access sites have parking and toilet facilities. Fish from the Sacramento-San Joaquin Delta have spread throughout the aqueduct system. Many types of fish can be caught, depending on the area. Striped bass and catfish are caught throughout the system, and starry flounder have been caught in the reach between Bethany Reservoir and O'Neill Forebay. Visits at the fishing access sites between 1971 and 1990 totaled 469,000, and total walk-in fishing between 1973 and 1990 was 893,000.

DWR has an active aqueduct safety program. Water contact is not allowed under any circumstances because without help it is almost impossible to climb out, except by using the emergency safety ladders. Brochures such as *Safety Along the State Water Project* and *California Aqueduct Fishing Safety* are published in several languages. DWR personnel also visit local communities near the aqueduct and conduct safety seminars for schools and community groups.

Drought Impacts on Recreation

Direct Effects on Facility Availability

Droughts have obvious impacts on water-oriented recreation, particularly if they are extended, like the 1987-92 drought in California. During this drought, the runoff of major California rivers averaged about 50 percent of normal and the carryover (September 30) storage in 155 major California reservoirs averaged about two-thirds of normal. So, major reservoirs were much less full than usual, and many reservoirs did not fill each spring as they normally do. This was also true of large natural lakes in California, such as Lake Tahoe, which was below its natural outlet for more than two years; Goose Lake, which almost dried up; and lower levels in Eagle Lake and Clear Lake.

Reservoir Recreation Impacts

The lower lake levels during droughts have had a variety of impacts on recreation. These impacts at lakes and reservoirs included the water surface receding far from developed recreation facilities such as campgrounds, picnic areas, and swimming beaches; boat ramps and swimming areas becoming unusable because they were no longer covered by water; boating and water skiing being reduced by declining surface area; and aesthetic values being generally reduced. Recreation attendance drops substantially when water levels drop well below major recreation facilities and boat ramps. During the 1976-77 drought, total attendance at State and federal reservoirs in California was reduced about 30 percent, with some reservoirs experiencing declines of as much as 80 percent, while attendance at a few stable reservoirs actually increased. A similar pattern developed during the 1987-92 drought although there were even fewer stable reservoirs.

Several years of low lake levels have sharpened the desire of many recreation area operators, and water agencies, to store as much water as possible. The extremes in annual precipitation within the last decade have accentuated the consequences of insufficient flood control capacity, as well as the impacts on recreation facilities when spring runoff does not materialize. The floods of 1983 and 1986 are still relatively recent, but the importance of flood control can be too easily dismissed following these several years of drought. It is important to emphasize that a prudent capacity reserve for flood control throughout the winter and spring months is vital. Property damage and liability resulting from flood mismanagement would have the potential to exceed the economic impact of less storage and reduced water deliveries. As with other project purposes, flood control releases must be accepted as a necessary trade-off against maximizing storage for recreation benefits.

River Recreation Impacts

White-water boating, river floating, and rafting are popular recreation activities in California. Low river levels reduce the length of the boating season and change the types of craft that can be used. Commercial outfitters experience considerable financial loss in years with greatly reduced flow levels. On the other hand, many popular boating runs are on streams sustained by water releases from reservoirs.

Even during normal water years, the cold water fraction of reservoir storage is especially valuable for the maintenance of downstream fisheries. If the cold water is depleted, subsequent warm water releases can be lethal to sensitive species. Storage of sufficient cold water to meet downstream environmental needs throughout the summer and fall may limit flows available earlier in the year for rafting and other activities. Consideration of the importance of cold water storage is an important part of water allocation even though there may be a substantial volume of warm water available.

Winter Recreation Impacts

Drought has an enormous impact on the winter sports industry. During recent years some northern California ski resorts never opened and many others opened only for short periods of time. During the 1976–77 drought, attendance at ski resorts fell by nearly 50 percent from pre-drought levels. The impact of reduced attendance also extends to businesses that manufacture, sell, or rent winter sports equipment. The economic loss to the industry was estimated at $50 million over the two years of drought during 1976–77. No accurate figures are available to describe the impact of the 1987–92 drought on winter sports. However, a similar pattern of shortened seasons and reduced attendance, even though many areas installed artificial snow-making equipment, continued over a longer period of time and the total economic impact was very large, probably several hundred million dollars.

Most major California ski resorts employ artificial snow-making equipment to augment the local snowpack during the early part of the season, and during the drought. Snow-making machinery can consume copious quantities of water considering that resorts typically operate several units at a time and for many hours a day (assuming sufficiently low temperature). For example, at Mt. Reba, an average-sized resort, about a million gallons of water (3 acre-feet) will be consumed during a 14-hour overnight period. Over a season, a typical resort may apply several hundred acre-feet per year for snow-making during drought periods. Much of this water is not actually consumed since it normally creates runoff and is available for future consumption in the spring.

Channels wind around Delta islands providing habitat for hundreds of species, water for agricultural and industrial production, drinking water for two-thirds of the State's population, and waterways for fishing and boating. Runoff from 40 percent of California's land area flows into the Delta.

Chapter 10

The Sacramento-San Joaquin Delta

For decades, the Sacramento-San Joaquin Delta has been the focal point for a wide variety of water-related issues, generating more investigations than any other waterway system in California. It is the hub from which two-thirds of the State's population and millions of acres of agricultural land receive part or all of their supplies. The Delta provides habitat for many species of fish, birds, mammals, and plants while also supporting extensive farming and recreational activities. Many different interests have a vital stake in the Delta: farmers, fish and wildlife groups, environmentalists, boaters, people involved with shipping and navigation, and the people and industries that receive water from the Delta and the State's two largest export systems, the State Water Project and Central Valley Project.

At the middle of the last century, the Delta, an area of nearly 750,000 acres, was mostly a tidal marsh, part of an interconnected estuary system that included the Suisun Marsh and San Francisco Bay. Until reclaimed by levees, the Delta was a great inland lake during the flood season; when the flood waters receded, the network of sloughs and channels reappeared throughout the marsh. The Delta receives runoff from over 40 percent of the State's land area, including flows from the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras rivers, and their tributaries.

The Delta channels were first surveyed in 1841 and again in 1849 by Lt. Commander Cadwalader Ringgold of the U.S. Navy. These surveys helped open up the Delta and upstream communities to increased trade with the San Francisco Bay area. Already experiencing a population boom because of the Gold Rush, Delta and northern California communities expanded even more as travel to the area became easier and less expensive.

The development of today's Delta began in late 1850 when the Swamp Land Act conveyed ownership of all swamp and overflow land, including Delta marshes, from the federal government to the State. Proceeds from the State's sale of swamplands were to go toward reclaiming them. In 1861, the State legislature created the Board of Swamp and Overflowed Land Commissioners to manage reclamation projects. In 1866, the board's authority was transferred to county boards of supervisors.

Developers first thought levees about 4 feet high and 12 feet wide at the bottom would protect Delta lands from tides and river overflow. In the 1870s, small-scale reclamation projects were started on Rough and Ready Island and Roberts Island, but the peat soils showed their weakness as levee material. The peat soils would sink, blow away when dry, and develop deep cracks and fissures throughout the levee system. In the late 1870s, developers realized that hand- and horse-powered labor could not maintain the reclaimed Delta islands. Steam-powered dredges were brought in to move large volumes of alluvial soils from the river channels; the alluvial soils were needed to construct the large levees we see today. These dredges were capable of moving material at about half the cost of hand labor. After World War I, the number of operating dredges decreased greatly, as nearly all Delta marshland had been reclaimed.

Today the Delta is comprised of about 500,000 acres of rich farmland, much of which is now below sea level (see Figure 10-1), is interlaced with hundreds of miles of waterways, and relies on more than 1,000 miles of levees for protection against flooding. The interiors of some of the islands are as much as 25 feet below sea level because of the continuing loss of peat soil. Soil loss comes primarily from oxidation, compaction, and wind erosion (see Figure 10-2).

Water exports from the Delta began in 1940 after the Contra Costa Canal, a unit of the CVP, was completed. Beginning in 1951, water was exported at the CVP's Tracy Pumping Plant, supplying the Delta-Mendota Canal. The SWP began delivery of water through the South Bay Aqueduct in 1962 (through an interim connection to the CVP's Delta-Mendota Canal). The SWP then continued deliveries by pumping from the South Delta in 1967 (supplying the California Aqueduct) and from the North Delta beginning in late 1987 (supplying the North Bay Aqueduct). Export water is either uncontrolled winter runoff or is released from CVP and SWP reservoirs into the Sacramento River system north of the Delta.

To facilitate movement of Sacramento River water to pumping facilities in the South Delta, the U.S. Bureau of Reclamation completed the Delta Cross Channel in 1951. This channel connects the Sacramento River to Snodgrass Slough and the Mokelumne River system. The flow from the Sacramento River is controlled by two 60-foot gates at the Sacramento River near Walnut Grove. Downstream from the Delta Cross Channel, Georgiana Slough also connects the Sacramento River to the Mokelumne River system, moving Sacramento River water into the Central Delta.

This chapter briefly describes Delta flows, outlines key Delta issues, profiles the Delta water resources management and planning process, and presents the options presently being discussed. Some specific issues are discussed more thoroughly in context with other statewide water supply concerns in other chapters of this report. (For example, water quality concerns are discussed in Chapter 5, *Water Quality*.) Readers are encouraged to refer to the other chapters cited throughout this discussion.

Delta Flows

Most Delta issues are centered around the way water moves into, through, and out of the Delta. Fresh water flows in the Delta are typically much less than those caused by tides. Twice a day Pacific Ocean tides move into and out of the Delta (see Figure 10-3). The average incoming and outgoing Delta tidal flow is about 170,000 cubic feet per second. This is in contrast to the currently permitted combined SWP and CVP export capability of about 11,000 cfs.

The average calculated Delta outflow, water that flows through the Delta past Chipps Island to San Francisco Bay, is about 30,000 cfs or about 21 maf per year. The magnitude of this flow depends on Delta inflow, export, and depletions of channel water within the Delta. During the summer months of critically dry years, Delta outflow can be as low as 3,000 cfs. Fresh water moves into the Delta from three major sources: the Sacramento River, the San Joaquin River, and eastside streams. The Sacramento River (including the Yolo Bypass) contributes about 77 percent of the fresh water flows, the San Joaquin River contributes roughly 15 percent, and streams on the east side and the Mokelumne River provide the remainder. Salty water moves into the Delta with the tides, from Suisun and Honker bays in the west. Direct Delta exports are

Figure 10-1. The Sacramento–San Joaquin River Delta

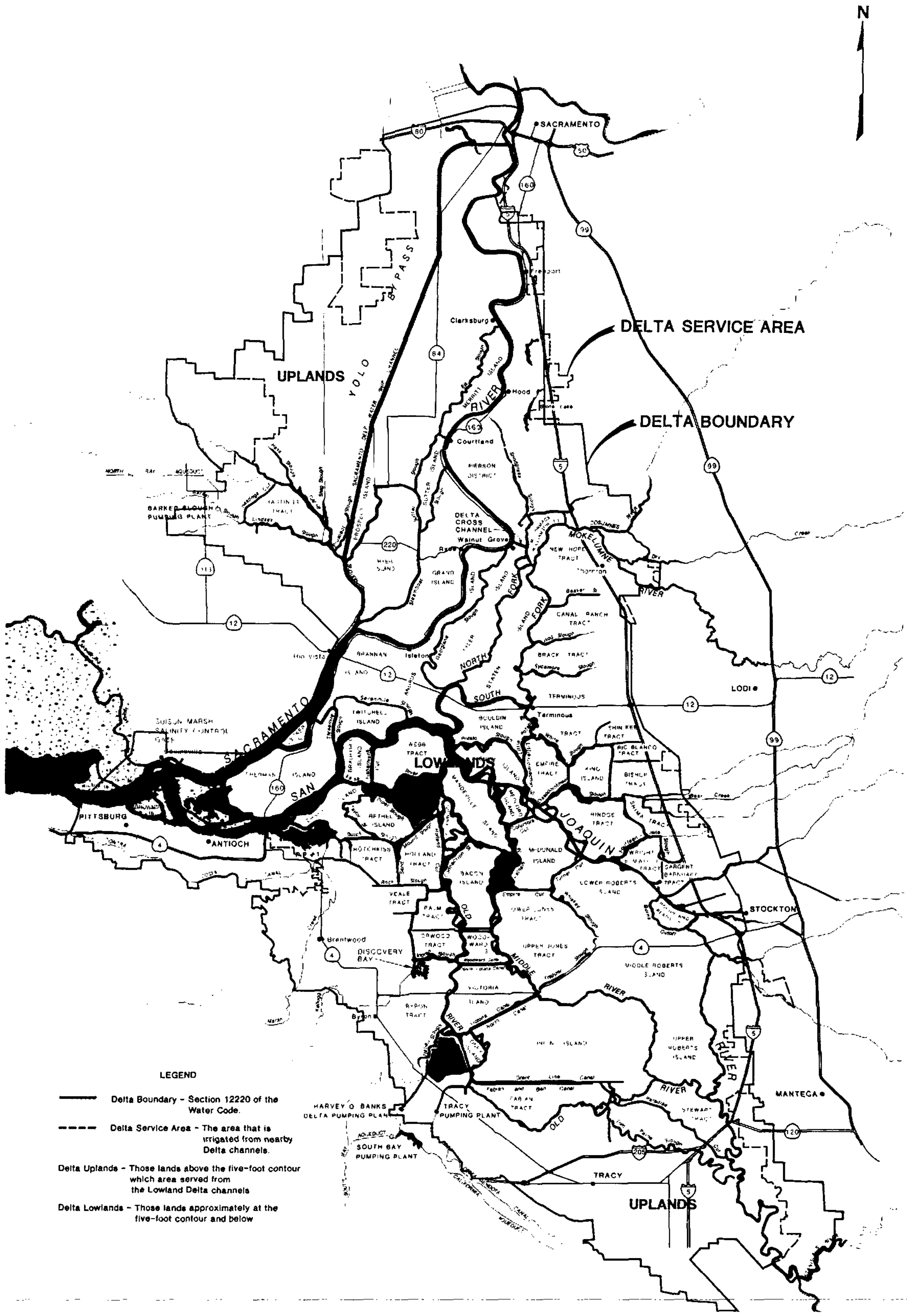

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Figure 10-2. Land Surface Below Sea Level, Sacramento–San Joaquin Delta

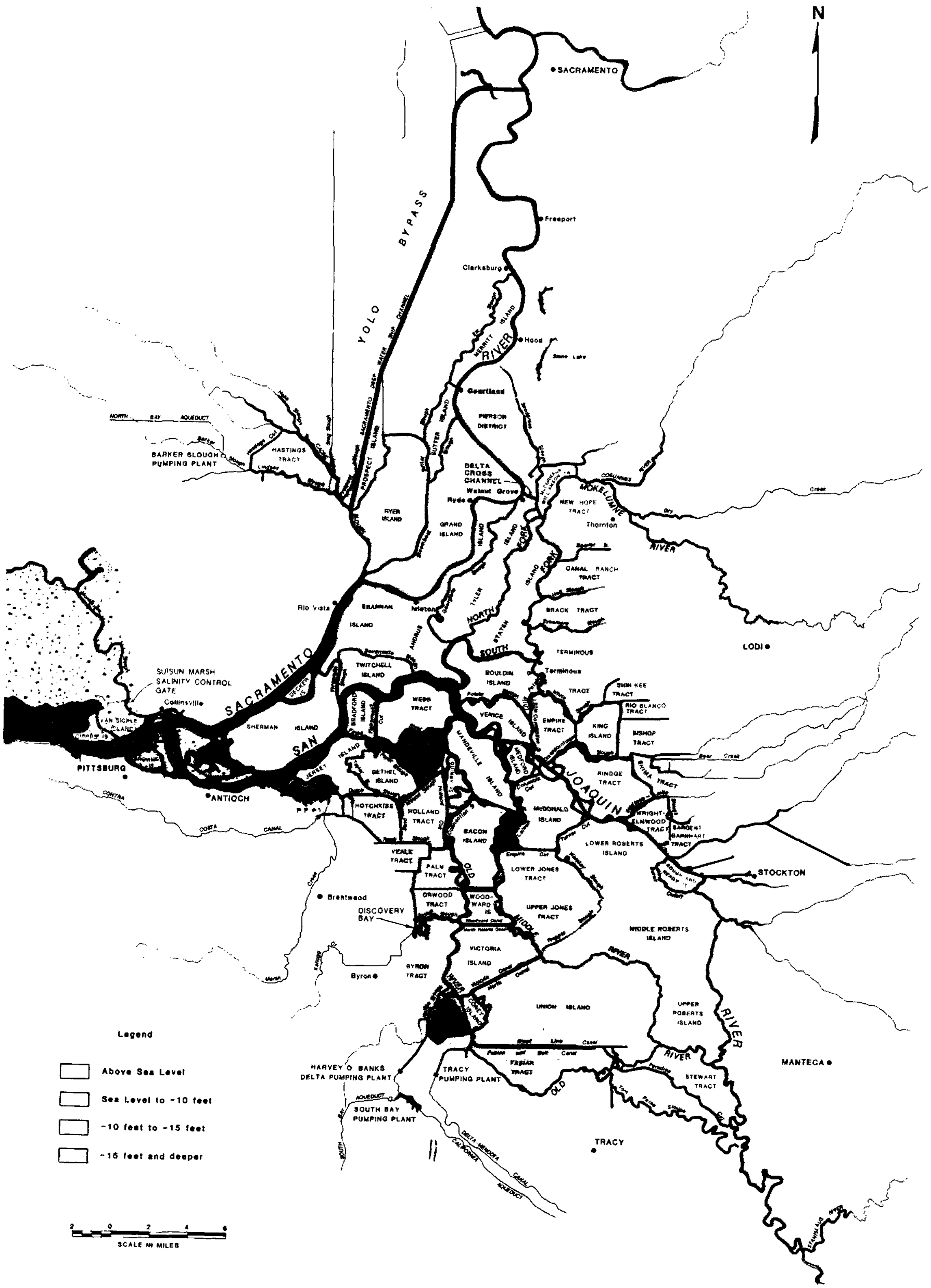

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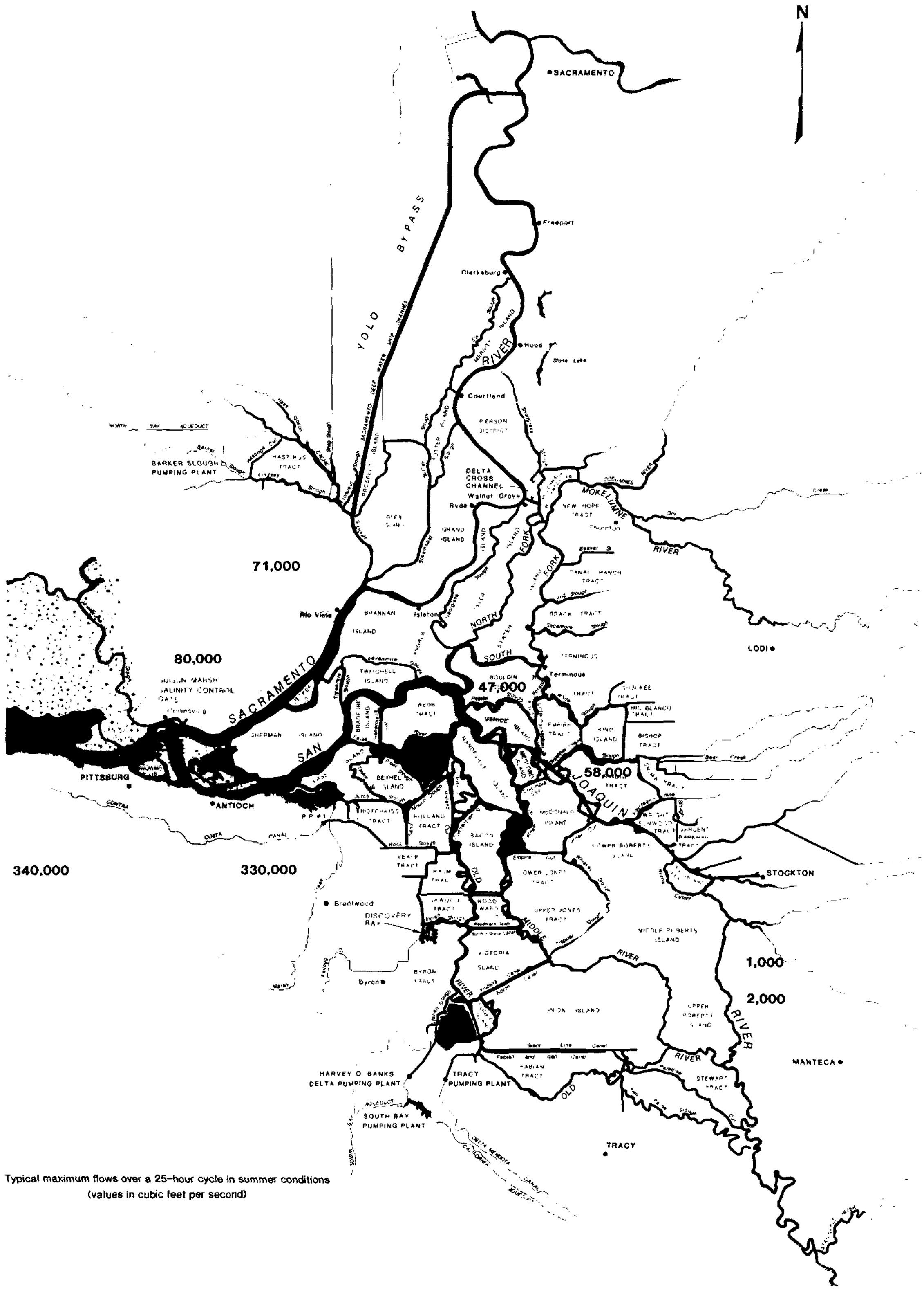
Figure 10-3. Tidal Flows in the Sacramento–San Joaquin Delta

(in cubic feet per second)



Typical maximum flows over a 25-hour cycle in summer conditions
(values in cubic feet per second)

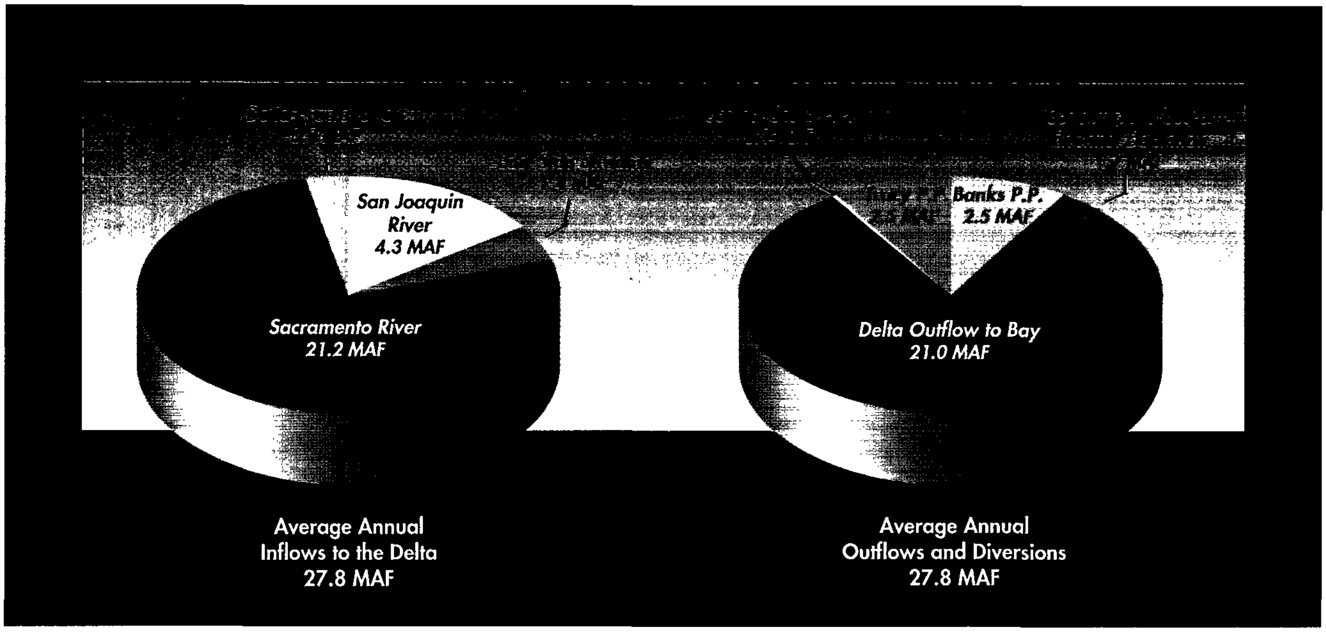


Figure 10-4. Delta Flow Components and Comparisons

made by the CVP, the SWP, and the City of Vallejo. Channel depletions occur due to crop irrigation, evaporation, and channel seepage in the Delta (see Figure 10-4).

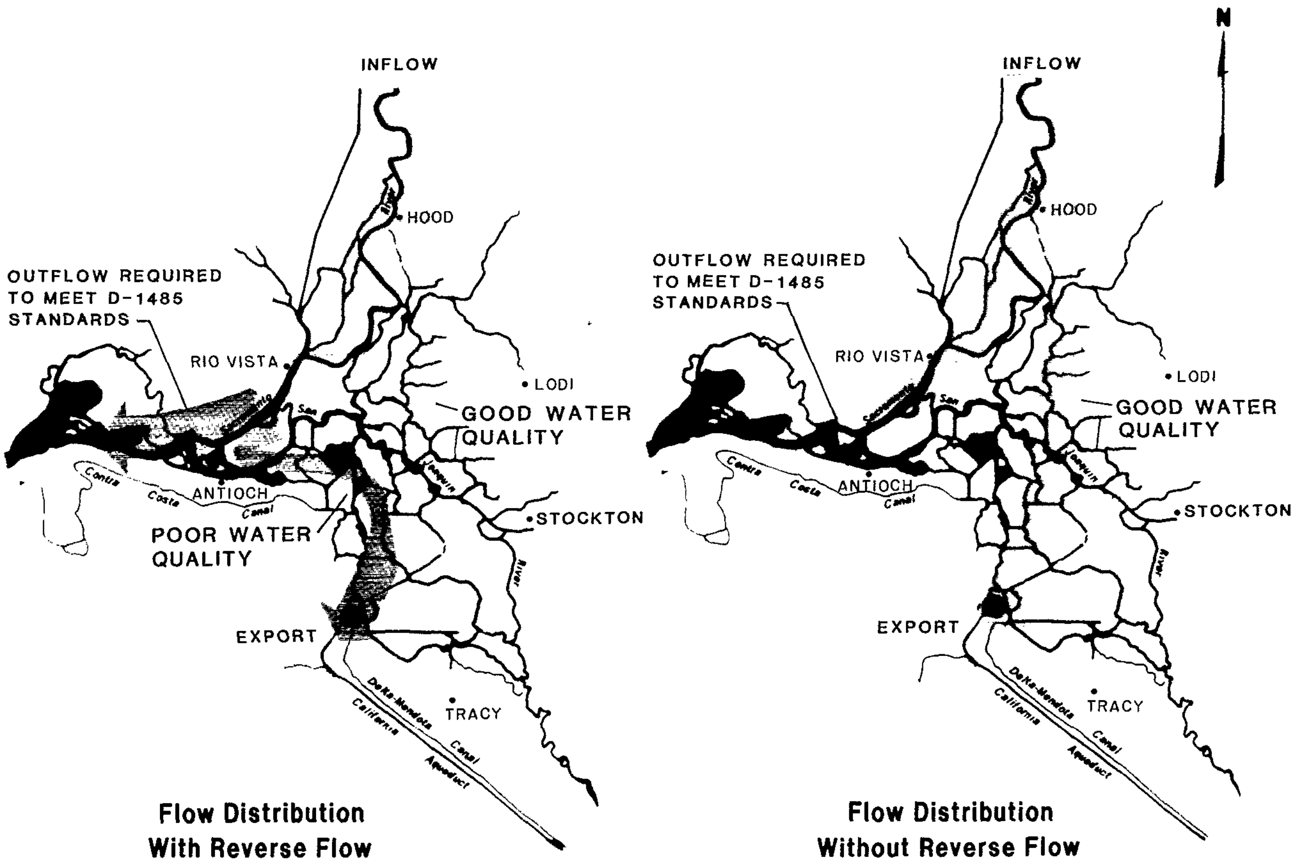
Today, minimum fresh water Delta outflow is maintained by releases from upstream storage reservoirs of the SWP and CVP. This outflow establishes a hydraulic barrier to prevent ocean water from intruding deep into the Delta and affecting municipal and agricultural water supplies. The hydraulic barrier, where fresh water gradually mixes with ocean water, is generally maintained near Chipps Island. During flood flows, the hydraulic barrier moves out into the Bay.

Reverse Flow and Carriage Water

The expression "reverse flow" characterizes a Delta flow problem that stems from the lack of capacity in certain channels leading to the export pumps (see Figure 10-5). CVP and SWP water supply exports are obtained from uncontrolled Delta inflows (when available) and from upstream reservoir releases when Delta inflow is low. Most of these uncontrolled flows and releases enter the Delta via the Sacramento River and then flow by various routes to the export pumps in the southern Delta. Some of these flows are drawn to the SWP and CVP pumps through interior Delta channels, facilitated by the CVP's Delta Cross Channel and a natural connection through Georgiana Slough. In some situations, these interior channels do not have enough capacity to meet Delta demands for agriculture and the demands of the pumps in the southern Delta.

The remaining water from the Sacramento River needed to meet pumping demand flows down the Sacramento River to Three-mile Slough and the western end of Sherman Island and up the San Joaquin River towards the pumps. When freshwater outflow is relatively low, water in the western Delta is brackish because fresh water from the Sacramento River mixes with saltier ocean water entering as tidal inflow from the San Francisco Bay. This water can be drawn upstream (reverse flow) into the San Joaquin River and other channels by pumping plant operations when San Joaquin River flow is low and pumping is high. The massive amount of water driven in and out of the Delta by tidal action dwarfs the actual fresh water outflow and considerably

Figure 10-5. Flow Distribution, With and Without Reverse Flows



complicates the reverse flow issue. Prolonged reverse flow can deteriorate water quality in the interior Delta and at the export pumps and harm fisheries.

Currently, during operational periods of reverse flow, more water than is needed for export must be released from project reservoirs to help repel intruding sea water, maintain required water quality in the Delta, and meet export quality standards. This incremental release of water from the reservoirs is termed *carriage water.* Carriage water is a function of Delta export, South Delta inflow, tidal cycle, and operation of the Delta Cross Channel gates. If the Delta Cross Channel gates are closed when pumping rates are high and the Delta is under controlled conditions, more water must be released to repel salinity intrusion.

Key Delta Issues

Fish and Wildlife Issues

Summarized here are Bay/Delta fish and wildlife issues that are discussed in more detail in Chapter 8, *Environmental Water Use.* Chapter 12, *Water Supply and Demand Balance,* presents a range of hypothetical environmental water requirements that could provide additional Delta outflow, with the intent of improving reliability of supply for environmental protection of aquatic species in the Delta. Water diversions and their relationship to fish in the Delta are discussed here.

Delta fish are affected by a number of physical and biological problems including: inflow that is reduced by upstream uses, upstream diversions that bypass the

Delta, direct diversions from the Delta itself, and changes to the food chain from the introduction of nonnative aquatic species, toxics, and legal and illegal harvest. Direct diversions include those by power plants and industries in the western Delta; 1,800 local agricultural diversions; the North Bay Aqueduct, serving the northern Bay area; the Contra Costa Canal, serving the eastern San Francisco Bay Region; and the southern Delta diversions by the CVP and the SWP, which serve the southern Bay Area, the San Joaquin Valley, and Southern California.

Fish screens and protection facilities have been constructed for the North Bay Aqueduct, the CVP's Tracy Pumping Plant, and the SWP's H.O. Banks Delta Pumping Plant. Water rights Decision 1485 mandates that the CVP and SWP exports be curtailed during certain months to protect fish and that flows be maintained for protecting the Delta environment. Concern about entrainment losses due to Delta agricultural diversions has also resulted in fish screening requirements being established in the Fish and Game Code. In April 1992, DWR implemented a three-year Delta Agricultural Diversion Evaluation Program, with the objectives of developing reliable data about entrainment, determining the susceptibility of various fish species, and testing the effectiveness of experimental fish screens. (See the *Agricultural Diversion Screening* section later in this chapter.) Other protections include screens and special mitigation measures for the Pacific Gas and Electric Company's power plant diversions in the western Delta. Even with these measures, the need for a better understanding of the aquatic environment and more protection is evident, because some Delta fish are continuing to decline.

The general decline of several fish, the Delta smelt and winter-run salmon in particular, has generated much concern and has ultimately resulted in both cited species being listed under the federal Endangered Species Act. Two other species, the longfin smelt and the splittail, have also been petitioned for listing. The listing of species has considerably curtailed SWP and CVP diversions from the Delta, making those supplies less reliable and more uncertain for urban and agricultural users.

Local Issues

Local Delta water use is protected by a number of measures, such as the Delta Protection Act, the Watershed Protection Law, and water rights. DWR negotiated additional agreements to provide protection in connection with specific local problems.

The most pressing problem in the north Delta area is repeated and extensive flooding of the leveed tracts and islands. Levee failures have become common and there have been 14 levee breaks in the north Delta since 1980. Flooding problems are not limited to the north Delta. There have been 17 levee breaks since 1980 throughout the Delta. Both the limited channel capacities and the inadequate, deteriorating non-project, or local, levees contribute to this critical problem.

Factors that affect South Delta water levels and water availability at some local diversion points are natural tidal fluctuations, San Joaquin River inflow, local agricultural diversions and returns, inadequate channel capacities, and SWP and CVP operations. Poor San Joaquin River water quality combined with local agricultural drainage returns, aggravated by poor water circulation, has affected channel water quality, particularly in shallow, stagnant, or dead-end channels. Channels that are too shallow and narrow also restrict flow and the volume of water available for export pumping. Recently, DWR entered into an agreement with the South Delta Water Agency and the USBR to develop long-term solutions for the SDWA's water problems.

DWR negotiated several long-term agreements with various local entities to protect their use of water from adverse project impacts. To protect agricultural uses, contracts were executed with the North Delta Water Agency and the East Contra Costa Irrigation District. To protect municipal uses, contracts were negotiated with the Contra Costa Water District and the City of Antioch. Industries near Antioch and Pittsburg use offshore water for processing. DWR signed two contracts (in 1987 and 1991) with Gaylord Container Corporation. DWR occasionally pays for providing substitute water through the Contra Costa Canal when offshore water quality falls below the industries' requirements.

A Delta Protection Commission was established by the Delta Protection Act of 1992 for management of land resources within the Delta. The commission is to develop a long-term resource management plan for the Delta "Primary Zone." As stated in the Act, the goals of this regional plan are to "protect, maintain, and where possible, enhance and restore the overall quality of the Delta environment, including, but not limited to, agriculture, wildlife habitat, and recreational activities." The Act acknowledges that agricultural land within the Delta is of significant value as open space and habitat for waterfowl using the Pacific Flyway. The regional plan is to protect agricultural land within the Primary Zone from the intrusion of nonagricultural uses.

Delta Water Quality Standards

Water quality control in California is regulated by the State Water Resources Control Board. From California's water supply perspective, perhaps the most important of the State's 16 water quality basin plans funded under California's Clean Water Bond Act of 1970 is the one for the Sacramento-San Joaquin Delta. The 1975 Basin Plan provided for protection of the Delta's varied beneficial water uses through a set of water quality objectives. These water quality objectives were similar to requirements in Decision 1379 by the SWRCB, a decision pertaining to water rights for the SWP and CVP.

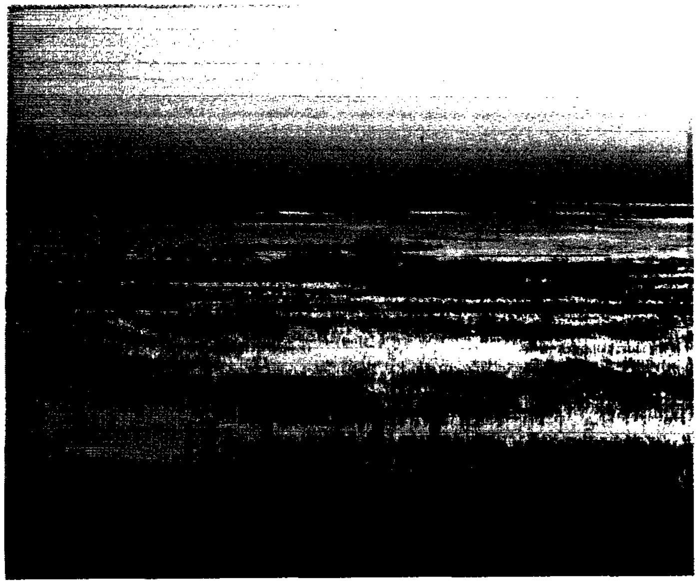
In August 1978, the SWRCB adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and the Suisun Marsh (the Delta Plan) and the corresponding water right Decision 1485, subsequent to D-1379 (1971). Both documents amended water quality standards relating to salinity control and fish and wildlife protection in the San Francisco Bay-Delta estuary in the 1975 Basin Plan. D-1485 standards are generally based on the degree of protection that municipal, industrial, agricultural, and fish and wildlife uses would otherwise have experienced, had the SWP and CVP not been built. D-1485 standards required that the SWP and CVP make operational decisions to maintain Delta water quality and to meet Delta freshwater outflow within specified limits. About 5 maf of Delta outflow is required in an average year to meet D-1485 salinity standards.

To help implement these water quality standards, D-1485 mandated an extensive monitoring program. It also called for special studies to provide critical data about major concerns in the Delta and Suisun Marsh for which information was insufficient. D-1485 included water quality standards for Suisun Marsh as well as for the Delta, requiring DWR and the USBR to develop a plan for the marsh that would ensure meeting long-term standards for full protection by October 1984 (later extended to October 1988).

Recognizing that the complexities of project operations and water quality conditions would change over time, the SWRCB also specified that the Delta water right permit hearings would be reopened, depending upon changing conditions in the Bay/ Delta region and the availability of new evidence on beneficial uses of water.

The following brief discussions of the *Racanelli Decision* and the SWRCB Bay-Delta Proceedings are repeated from Chapter 2, *Institutional Framework*. These issues

The State Water Resources Control Board's Water Right Decision 1485 recognized the Suisun Marsh as an important brackish marsh. D-1485 required that a plan for protecting the marsh be implemented by October 1984. The plan is being implemented in phases, and Phases I and II have been completed.



are vitally important to the Delta and have institutional implications.

Racanelli Decision

Lawsuits by various interests challenged Decision 1485, and the decision was overturned by the trial court in 1984. Unlike its predecessor, D-1379, whose standards had been judicially stayed, D-1485 remained in effect. In 1986, the appellate court in the *Racanelli Decision* (named after Judge Racanelli who wrote the opinion) broadly interpreted the SWRCB's authority and obligation to establish water quality objectives and its authority to set water rights permit terms and conditions that provide reasonable protection of beneficial uses of Delta water and of San Francisco Bay. The court stated that SWRCB needed to separate its water quality planning and water rights functions. SWRCB needs to maintain a "global perspective" both in identifying beneficial uses to be protected (not limited to water rights) and in allocating responsibility for implementing water quality objectives (not just to the SWP and CVP, nor only through the Board's own water rights processes). The court recognized the SWRCB's authority to look to all water rights holders to implement water quality standards and advised the Board to consider the effects of all Delta and upstream water users in setting and implementing water quality standards in the Delta, as well as those of the SWP and the CVP.

SWRCB Bay–Delta Proceedings

Hearings to adopt a water quality control plan and water rights decision for the Bay–Delta estuary began in July 1987. Their purpose was to develop a San Francisco Bay/Sacramento–San Joaquin Delta water quality control plan and to consider public interest issues related to Delta water rights, including implementation of water quality objectives. During the first phase of the proceedings, State and federal agencies, including DWR, public interest groups, and agricultural and urban water purveyors provided many expert witnesses to testify on a variety of issues pertaining to the reasonable and beneficial uses of the estuary's water. This phase took place over six months, and generated volumes of transcripts and exhibits.

The SWRCB released a draft *Water Quality Control Plan for Salinity and Pollutant Policy Document* in November 1988. However, the draft water quality control plan, a significant departure from the 1978 plan, generated considerable controversy throughout the State. The Pollutant Policy Document was subsequently adopted in June 1990.

In January 1989, the SWRCB decided to significantly amend the draft plan and redesign the hearing process. The water quality phase was to continue, an additional scoping phase would follow, and issues related to flow were to be addressed in the final water rights phase. Concurrently, DWR and other agencies offered to hold a series of workshops to address the technical concerns raised by the draft plan. These workshops were open to the public and benefited all parties involved by facilitating a thorough discussion of technical issues. After many workshops and revisions to the water quality control plan, the SWRCB adopted a final plan in May 1991. The federal EPA rejected this plan in September 1991.

With the adoption of the Water Quality Control Plan, the SWRCB began the EIR scoping phase and held several workshops during 1991 to receive testimony regarding planning activities, facilities development, negotiated settlements, and flow objectives. The goal was to adopt an EIR and a water right decision by the end of 1992.

In response to the Governor's April 1992 water policy statement, SWRCB decided to proceed with a process to establish interim Bay-Delta standards to provide immediate protection for fish and wildlife. Water right hearings were conducted from July through August 1992, and draft interim standards (proposed Water Right Decision 1630) were released for public review in December 1992. Concurrently, under the broad authority of the Endangered Species Act, the federal regulatory process was proceeding toward development of Delta standards and upstream measures applicable to the CVP and SWP for the protection of the threatened winter-run chinook salmon. In February 1993, the National Marine Fisheries Service issued a long-term biological opinion governing operations of the CVP and SWP with Delta environmental regulations that in certain months were more restrictive than SWRCB's proposed measures. On March 1, 1993, the U.S. Fish and Wildlife Service officially listed the Delta smelt as a threatened species and shortly thereafter indicated that further restrictions of CVP and SWP operations would be required.

In April 1993, the Governor asked the SWRCB to withdraw its proposed Decision 1630 and instead focus efforts on establishing permanent standards for protection of the Delta since recent federal actions had effectively preempted State interim standards and provided interim protection for the Bay-Delta environment. On December 15, 1993, EPA announced its proposed standards for the estuary in place of SWRCB water quality standards EPA had rejected in 1991; USFWS proposed to list the Sacramento splittail as a threatened species; and NMFS announced its decision to change the status of winter-run salmon from threatened to endangered.

In April 1994, the SWRCB began a series of workshops to review Delta protection standards adopted in its 1991 Water Quality Control Plan for Salinity and to examine proposed federal EPA standards issued in December 1993. These processes seek to involve both SWRCB and EPA and are intended to establish a mutually acceptable draft SWRCB Delta regulatory plan scheduled for release in December 1994. The plan will be developed in accordance with the Triennial Review requirements of the Clean Water Act.

Meeting Water Quality Standards

Water quality of the Sacramento-San Joaquin Delta is generally satisfactory for agriculture. However, the quality of the Delta water could potentially pose problems to the municipal water purveyors charged with treating the water to meet anticipated federal standards for trihalomethanes and new standards for other disinfection byproducts. More stringent standards could force many water purveyors to spend billions of dollars for additional treatment.

Precursors of trihalomethane (THMs) formation include naturally occurring dissolved organic matter and bromides. Dissolved organic matter is present in Delta drainage water primarily as a result of the decomposition of plants, such as the decayed Delta marsh lands. Bromide is present in sea water and is introduced into the Delta when fresh water is mixed with ocean water by tidal action. The degree to which saline water penetrates into the Delta is a function of the interaction of the high and low tides, fresh-water outflow, Delta export, diversions from the Delta channels, and atmospheric conditions.

Because THMs can potentially cause cancer, the EPA in 1979 set the standard for trihalomethanes in treated drinking water at 0.10 milligram per liter or 100 parts per billion. One ppb would be the equivalent to two drops in a large backyard swimming pool (25,000 gallons).

It will be difficult or perhaps impossible with existing facilities for water utilities to achieve compliance with stricter standards for THMs. Urban purveyors of Delta water, who serve two-thirds of the State's population, will be forced to redesign their existing water treatment facilities or limit Delta exports when water quality is not suitable unless a solution is found to improve the quality of export water for urban purveyors. Water quality considerations are presented in more detail in Chapter 5.

Flooding in the Delta

The reliability of Delta water supplies, in terms of water quality, could be affected by levee failures caused by poor levee maintenance, levee instability, high water, or earthquakes. Protection of certain islands in the western Delta is particularly important because water quality can be degraded by intrusion of brackish water. Large volumes of brackish water could rush into the Delta and deteriorate Delta water quality if a levee were to fail. Permanent flooding of western Delta islands could increase the upstream movement of ocean salts, requiring projects upstream of the Delta to provide more outflow to repel the salt and maintain water quality in the Delta and at the pumps.

A levee on Tyler Island in the north Delta breaches during the 1986 floods. In all, six Delta islands and tracts flooded, as did Interstate 5 and numerous local roads. The flooding forced 1,600 people to evacuate and cost $20 million in direct damage.

Stability of Delta Levees

The levees act as the only barriers between low-lying land and water in the Delta. Behind these earthen walls lie about half a million acres of agricultural land and wildlife habitat; many small communities; and numerous roads, railroad lines, and utilities. Delta islands, which commonly lie 10 to 15 feet below sea level and are composed in part of highly organic (peat) soils, are constantly in danger of further land subsidence and seepage. The original levees were constructed to heights of about 4 feet and founded on the soft, organic Delta soils. Due to continued subsidence of the levees and island interiors, it is necessary to continually add material to maintain freeboard and structural stability. Over the last century, many of the levees have significantly increased in size and now average between 15 and 25 feet high. The increasing levee height has meant an increased threat of failure which requires increasing maintenance and repair costs just to prevent further deterioration of levee conditions. The Delta Flood Protection Act enacted in 1988 (see below) has provided the impetus toward levee improvement rather than just maintaining the status quo.

Delta levees are classified as either project or nonproject levees. Project levees are part of the federal flood control project. Mostly found along the Sacramento and San Joaquin rivers, they are generally maintained to Army Corps of Engineers standards and provide dependable protection. Nonproject, or local, levees (three-fourths of the Delta levees) are those constructed and maintained to varying degrees by island landowners or local reclamation districts. Most of these levees have not been brought up to federal standards and are less stable, thereby increasing the chances of flooding.

The Delta Levee Subventions Program, originally known as the "Way Bill" program, began in 1973. The bill authorized funding for levee maintenance and rehabilitation costs, with up to 50-percent reimbursement to local agencies. The funding for these reclamation projects has grown from $200,000 annually in the 1970s to $2 million annually in the 1980s, with a 50-percent reimbursement rate to local districts.

Seventeen islands have been partially or completely flooded since 1980, costing roughly $100 million for property recovery and repairs. As a result of floods in 1986, the Delta Flood Protection Act (Senate Bill 34) was enacted in 1988. Through the Act, funding for the Delta Subventions Program increased up to $6 million a year and allowed up to 75-percent reimbursement to the local agencies for their levee work. Another $6 million is directed toward implementing special flood control projects. Recent activities include planning and designing major levee rehabilitation projects for Twitchell Island and New Hope Tract; repair of threatened levee sites on Sherman Island, Twitchell Island, Bethel Island, and Webb Tract; and other special projects and studies to determine the causes of Delta land subsidence.

The levees are also potentially threatened by earthquake activity. Several active faults—the Antioch, Greenville, and Coast Range Sierra Nevada Boundary Zone faults—are west of the Delta and are capable of delivering moderate to heavy shaking. There has been continuous concern about the potential for liquefaction of the levees and of the foundation materials on some islands. There is no record of a levee failure resulting from earthquake shaking; however, many experts believe that the levee system has not really been tested by substantial earthquake shaking. Several studies indicate there will probably be levee damage or failure induced by earthquake shaking within the next 30 years. Further investigations will better define the expected performance of the levees during earthquakes.

Delta Water Resource Management and Planning

Because of its importance to the state- wide water supply, the Sacramento-San Joaquin Delta is the most studied body of water in the State. No one in California disputes the need to improve water transfer efficiency, min-imize land subsidence and flooding, and im-prove conditions for fish and wildlife. The issue is not whether the Delta should be fixed, but rather how the Delta problems should be resolved.

Planning for Delta improvements to address sea water intrusion into the Delta has been under way since the late 1800s. Ocean salinity intrusion into the Delta was first noted in 1841, long before any upstream water development was in place. Planning began with an 1874 report by the U.S. Army Corps of Engineers suggesting use of Sacramento Valley water to irrigate both the Sacramento and San Joaquin valleys. That report was followed by a comprehensive State plan for water development issued in 1919 by Col. Robert B. Marshall, a topographer with the U.S. Geological Survey. Our present State water system includes many of Marshall's ideas. Reviewing the plan in 1926, the California Water Resources Association commented:

> *. . .whatever plan the Department of Public Works may recommend, (it) must. . .make some feasible and satisfactory recommendation covering the extremely grave problem of salt water encroachment in the Delta. . . . This is one of the most vital considerations before the people of California today. . . .*

Since then, there have been numerous studies for controlling salinity intrusion and improving the water resources management of the Delta for the benefit of all Californians.

Past Delta Water Management Programs

Four broad concepts have been studied for the Delta. These are:

- physical barriers
- hydraulic barriers
- through–Delta facilities
- isolated facilities

During the last 50 years a variety of proposals modifying or combining all these concepts have been suggested to improve Delta conditions and to allow for beneficial use of Delta water supplies.

Physical barriers to separate salt and fresh water were predominant in early studies. During the 1940s and 1950s salt water barriers at numerous sites on the Bay and Delta system were again studied in detail. However, it was recognized that barriers in the San Francisco Bay system would not be functionally feasible and that further barrier consideration should be limited to, or upstream from, the Chipps Island site at the outlet of the Delta. Installation of barriers in major channels such as the one adjacent to Chipps Island would change the flow regime, change the location and area of the tidal mixing zone, affect the food chain in the Delta, and be an obstacle for shipping and migratory fish passing through the Delta.

Hydraulic barriers were also studied in early planning stages to repel salinity intrusion in the Delta. The thrust of hydraulic barrier studies was that water transfer through existing Delta channels for local use and export could be accompanied by water releases from upstream reservoirs to control salinity by outflow from the Delta. This was the basis of the proposals adopted for current SWP and CVP operations.

Through–Delta facilities were first studied in the late 1950s and were proposed by DWR in 1960 as the single–purpose Delta Water Project (later referred to as the Waterway Control Plan). This alternative proposed such actions as enlarging Delta channels, closing channels, and constructing siphons, as well as moderate releases of water from upstream storage reservoirs for salinity control to improve movement of Sacramento River water to pumps in the South Delta. A similar concept was formulated in a plan proposed by DWR in 1983 under "Alternatives for Delta Water Transfer." The most recent through–Delta facility proposal is the North Delta Program, which addresses North Delta flooding issues in addition to improving conveyance capacity of North Delta channels to reduce reverse flow and salinity intrusion.

Isolated facilities would convey water around the Delta for local supply and export through a hydraulically isolated channel. Delta salinity control would be accomplished by a hydraulic barrier maintained by releases from upstream storage reservoirs. This concept was formulated in a plan proposed by the Interagency Delta Committee in 1965 as the Peripheral Canal. A statute that would have authorized this and many other additions to the SWP was rejected by the voters in 1982.

Current Delta Regulatory Decision-Making Process

Competing needs and various governmental agencies with different jurisdictional claims on the Delta have made today's Delta planning process more complex than ever. The Delta lies within five counties and is subject to various State and federal regulations. Consequently, Delta planning programs usually provide forums for many diverse interests and often generate much controversy. The challenge of Delta planning is to create a planning strategy that can balance the diverse and often conflicting interests.

Today, the decision-making process is slow and complicated by an intricate web of institutional constraints and the number of parties involved. This has made resolution of Delta problems a divided and sometimes disjointed process. Thus far, no consensus has been reached. Local, regional, State, and federal agencies, as well as environmental and economic concerns, all play a role in the Delta planning and decision-making process. Delta management decisions are made at every level of government. DWR is just one component in this complex puzzle. The trend, in recent years, has been toward more involvement of federal regulatory agencies in Delta water management planning.

Among the agencies regulating water use from the Sacramento-San Joaquin river system are:

State Water Resources Control Board	U.S. National Marine Fisheries Service
California Department of Fish and Game	U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service	U.S. Army Corps of Engineers

These agencies exercise regulatory control and enforce statutes that include the State and federal endangered species acts, the federal Clean Water Act, and water rights. These laws are discussed in Chapter 2, *The Institutional Framework for Water Management in California*. How these laws affect Delta planning and the agencies involved are discussed here.

Virtually anything that can be done to resolve Delta problems will require permits from a number of agencies. Potential permits required for Delta program implementation are shown in Table 10-1. The environmental documentation process, regulatory permits, and compliance with requirements of the endangered species acts are the most important components of the decision-making process. The following sections discuss the environmental review process, regulatory permits, and the endangered species acts as they relate to Delta planning. Figure 10-6 is a flow chart showing the interrelationships of these three components in the Delta decision-making process.

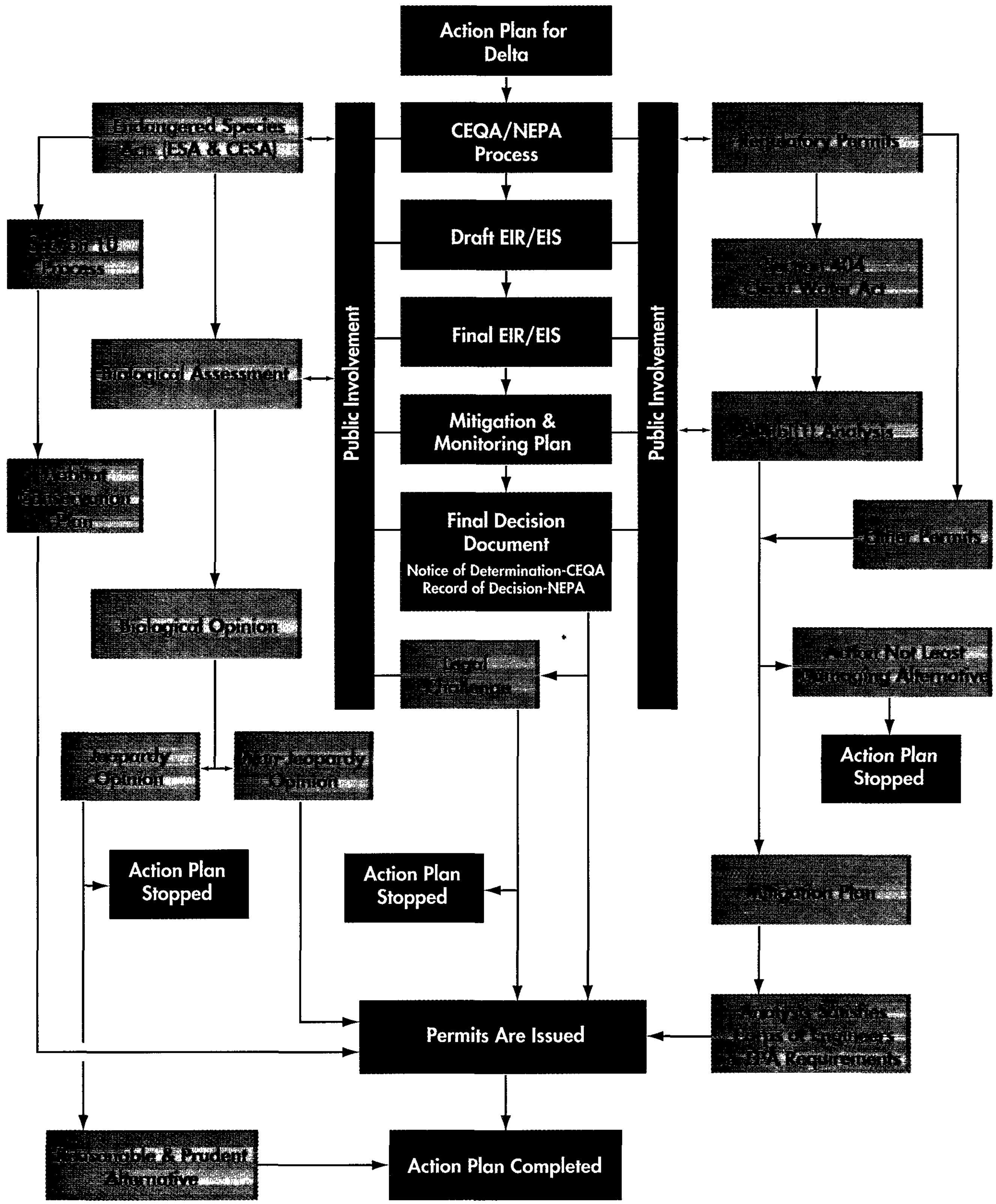
Environmental Review Process. Both the National Environmental Policy Act and the California Environmental Quality Act require decision makers to document and consider the environmental impacts of their actions and encourage public participation in the decision-making process. Both CEQA and NEPA processes start with a formal public notice announcing to the public and concerned agencies that the planning and environmental documentation process has begun and that public input is sought. Public scoping meetings are held to solicit public input in determining the scope of the environmental document. A draft environmental document is then prepared and released for public review and comments. The draft document includes a comprehensive evaluation of alternatives and their impacts along with potential mitigation measures. Successful completion of the environmental documentation process

Table 10-1. Major Permits Required for Implementation of Delta Water Management Programs

Agency	*Permit Description*	*Permit Conditions*
Corps of Engineers (in coordination with U.S. Fish and Wildlife Service and Environmental Protection Agency)	Dredging Permit (Section 404, Clean Water Act)	Required for any proposal to locate a structure, excavate, or discharge dredged or fill materials into waters of the United States or to transport dredged material for the purpose of dumping it into ocean waters.
	Navigation Permit (Section 10, Rivers and Harbors Act)	Required for any proposal to divert or alter navigable waters in the United States, including wetlands.
National Marine Fisheries Service	Incidental Take Permit	Required for any action that may result in the take of listed anadromous species. Permit is issued under authority of ESA.
U.S. Fish and Wildlife Service	Incidental Take Permit	Required for any action that may result in the take of listed species. Permit is issued under the authority of ESA.
Department of Fish and Game	Navigation Dredging Permit	Required for any proposal to use suction or vacuum dredging equipment in any river, stream, or lake designated as open.
	Stream or Lakeside Alteration Agreement	Required for any activity that will change the natural state of any river, stream, or lake in California.
	Permit or MOU	Required for any action that may result in the take of a State listed species.
Caltrans	Encroachment Permit	Required for any proposal to do work or place an encroachment on or near a State highway or proposal to develop and maintain access to or from any State highway.
	Utility Encroachment Permit	Required for work done by public utility companies provisioning services, such as gas, electricity, telephone, for most work within the right of way of a State highway.
State Lands Commission	Notice of Proposed Use of State Lands	Notice is sent to the State Lands Commission for any proposed SWP or CVP projects in the Delta for review and concurrence.
The Reclamation Board	Encroachment Permit	Required for any activity along or near the banks of the Sacramento and San Joaquin rivers or their tributaries. The Reclamation Board also issues encroachment permits for activity on any "designated floodway" or flood control plan adopted by the Legislature or the Board within the Central Valley.
State Water Resources Control Board	Permit to Appropriate Water	Required for any proposal to divert water from a surface stream or other body of water for use on nonriparian land or any proposal to store unappropriated surface water seasonally.
Department of Water Resources, Division of Safety of Dams	Approval of Plans and Specifications and Certificate of Approval	Required for any proposal to constrict or enlarge a dam 25 feet or more in height or impounding a reservoir with a capacity of more than 50 AF.
Regional Water Quality Control Board	Waste Discharge Requirement	Required for any actions that may result in the discharge or potential discharge of waste to Delta water.

depends on an agency's ability to adequately evaluate and address public comments and to build consensus and support for the action. Environmental interests, water users, and local entities in the Delta all have a great interest in any major decisions made for the Delta. For any Delta water planning decision to be acceptable, it should protect

Figure 10-6. Delta Decision-Making Process



Delta islands from flooding, ensure a reliable water supply of suitable quality for Delta water users, and guarantee environmental protection for fish and wildlife.

Regulatory Permits. Implementation of a comprehensive program for the Delta requires a number of permits, including permits under Section 404 of the federal Clean Water Act and Section 10 of the Rivers and Harbors Act. These two permits are administered by the U.S. Army Corps of Engineers. Section 404 regulates the discharge of dredged and fill materials into waters of the United States. Issuance of 404 permits requires EPA approval and coordination with USFWS. A Section 10 permit (Section 10 of the Rivers and Harbors Act) is required for obstruction of any navigable water including construction of dams or barriers. The Section 404 (b)(1) guidelines promulgated by the EPA state, "No discharge of dredged or fill materials shall be permitted if there is a practicable alternative to the proposed discharge which would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences." Any Delta program must comply with these guidelines by going through a comprehensive alternative analysis to determine the "least environmentally damaging practicable alternative." The alternative analysis along with environmental impacts analyses of the proposed action can be formulated within the framework of environmental documentation required by NEPA.

Endangered Species Acts. Requirements of the federal Endangered Species Act and the California Endangered Species Act have altered and now greatly affect water resources planning in the Delta. Two species, the winter-run chinook salmon and Delta smelt, were listed under the federal and State acts. These listings have changed the decision-making process for the Delta. In accordance with the ESA, a biological assessment should be prepared for any federal actions or permit applications in the Delta which may have impacts on listed and proposed species. The assessment contains information concerning listed and proposed species as well as material relating to the impacts of the proposed project on listed species. The biological assessment is used to determine whether formal consultation is required for the proposed action affecting the critical habitat or the species. Formal consultation is required if the listed species or their critical habitat are adversely affected by an action.

Based on the biological assessment, a biological opinion is prepared by either the USFWS or NMFS depending on the species. NMFS is responsible for ocean and anadromous species, while USFWS is the authority for inland species. The appropriate agency then determines whether the action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat. If the action would jeopardize the continued existence of the species, the opinion contains a reasonable and prudent alternative to avoid jeopardy. An incidental-take statement is issued when there may be a taking of a listed species incidental to the action that does not jeopardize the listed species' continued existence or critical habitat. For the projects that may have an impact on the listed species, but do not require any federal actions, a Section 10 (Section 10 of the ESA) incidental-take permit is required.

When a Delta decision is determined to affect species listed under both FESA and CESA, a State lead agency engages in a consultation with DFG. DFG also participates in the federal consultation process to ensure that the federal biological opinion findings are consistent with the State findings. In most cases, DFG would adopt the federal biological opinion.

Role of the U.S. EPA in the Delta

The U.S. EPA role in the Delta is as follows:

- EPA has the authority to veto permits issued by the Corps under Section 404 of the Clean Water Act if EPA determines that the project causes unacceptable adverse effects.
- The EPA has the authority to implement the Clean Water Act which, among other things, established a permit system to regulate point-source discharges in navigable waters of the United States, provided for control of nonpoint pollution sources, and required the EPA to establish effluent limitations and water quality criteria. Recently, EPA indicated that, under Clean Water Act authority, it will formulate water quality standards for the Delta. (In California, the authority to implement the Clean Water Act has been delegated to the SWRCB, although EPA retains the authority to step in when it determines State action is not adequate to protect the quality of U.S. waters.)
- The Federal Safe Drinking Water Act directed the EPA to set national standards for drinking water quality. EPA is currently reviewing the standards for THMs and other disinfectant byproducts with the intent of replacing them with stricter standards. This would have a significant impact on the urban water agencies receiving their water from the Delta. Thus, EPA actions through its jurisdiction under the Clean Water Act and the Federal Safe Drinking Water Act could significantly affect decisions for the Delta.

The federal government is playing a much greater role in determining what is ultimately to be done in the Delta than it has in the past. The Delta is an estuary and a navigable waterway subject to a number of significant federal laws because it includes wetlands and valuable anadromous fisheries. Any physical solution to Delta problems will require regulatory permits under Section 404 of the Clean Water Act and the endangered species acts. Over the years, activities necessary to obtain permits have evolved into complex and time-intensive processes.

Planning for the Delta generates controversy and promotes public and political debates. Actions by regulatory agencies are not isolated from these debates, and Delta planners recognize this complex relationship in formulating management strategies for the Delta. Such strategies require extensive coordination, cooperation, consultation, negotiation, and consensus between federal, State, and local entities. Building consensus for an action plan that would balance those interests and concerns of local entities requires extensive negotiations among agencies. The interrelationships between the environmental documentation process, permitting process, and endangered species actions are complex and continually changing. Delta planners are trying to find their way through an ever-changing maze of regulatory constraints surrounding the decision-making process in the Delta.

Options for Enhancing Urban Water Quality, Water Supply Reliability, and Improving Delta Environmental Conditions

The options discussed briefly here present some of the alternatives that are currently being evaluated or could be evaluated in the future. Protection of fish and wildlife and the ultimate Delta solution will determine the feasibility of several water supply programs. The following programs are intended to show the range of options being discussed by interest groups and water planners at this time.

Ongoing Delta Planning Programs

Interim South Delta Water Management Program. DWR recently evaluated the South, North, and West Delta programs to improve conditions in the Delta. The Interim South Delta Water Management Program is an important part of any water banking program and was implemented in response to an October 1986 agreement among DWR, USBR, and the South Delta Water Agency. The program also addresses the need to increase the operational flexibility and reliability of the SWP, including Los Banos Grandes, a south-of-the-Delta offstream storage project authorized in 1984. In the SDWA agreement, all three parties committed to developing mutually acceptable, long-term solutions to the water supply problems of local water users within SDWA.

The Interim South Delta Preferred Alternative consists of constructing interim facilities that include an additional SWP intake structure at Clifton Court Forebay, limited channel dredging, four flow-control structures, and a permit allowing the SWP to increase its existing pumping capacity. These facilities are intended to provide for operational flexibility to improve SWP water supply capability, reduce fishery impacts (particularly on San Joaquin River salmon populations), and improve water levels and circulation for local agricultural diverters.

A new multigate intake structure is proposed for the northeastern corner of the existing Clifton Court Forebay near the confluence of Old River and the Victoria and North canals as shown on Figure 10-7. This additional intake structure would be operated according to tidal water elevations to increase peak flow into the forebay. It would increase average daily diversion into the forebay and allow pumping at the H.O. Banks Delta Pumping Plant to the maximum design capacity of 10,300 cfs. Some channel dredging would be required to assure that channel scouring does not occur. This dredging would be in Old River north of the forebay.

Three of the four flow-control structures are proposed to control water levels, circulation, and the flow in the South Delta channels. The structures would be tidally operated during the irrigation season. Operations would retain flood tide flows in South Delta channels for a longer period of time to raise water levels. During other times of the year these control structures would be opened and would not affect local hydrology. The fourth, a control structure on Old River near the San Joaquin River, would be operated in the fall and spring to help salmon migrating in the San Joaquin River. During other times of the year this structure would not alter flows. The Interim South Delta Water Management Program could augment SWP supplies by about 60,000 af per year.

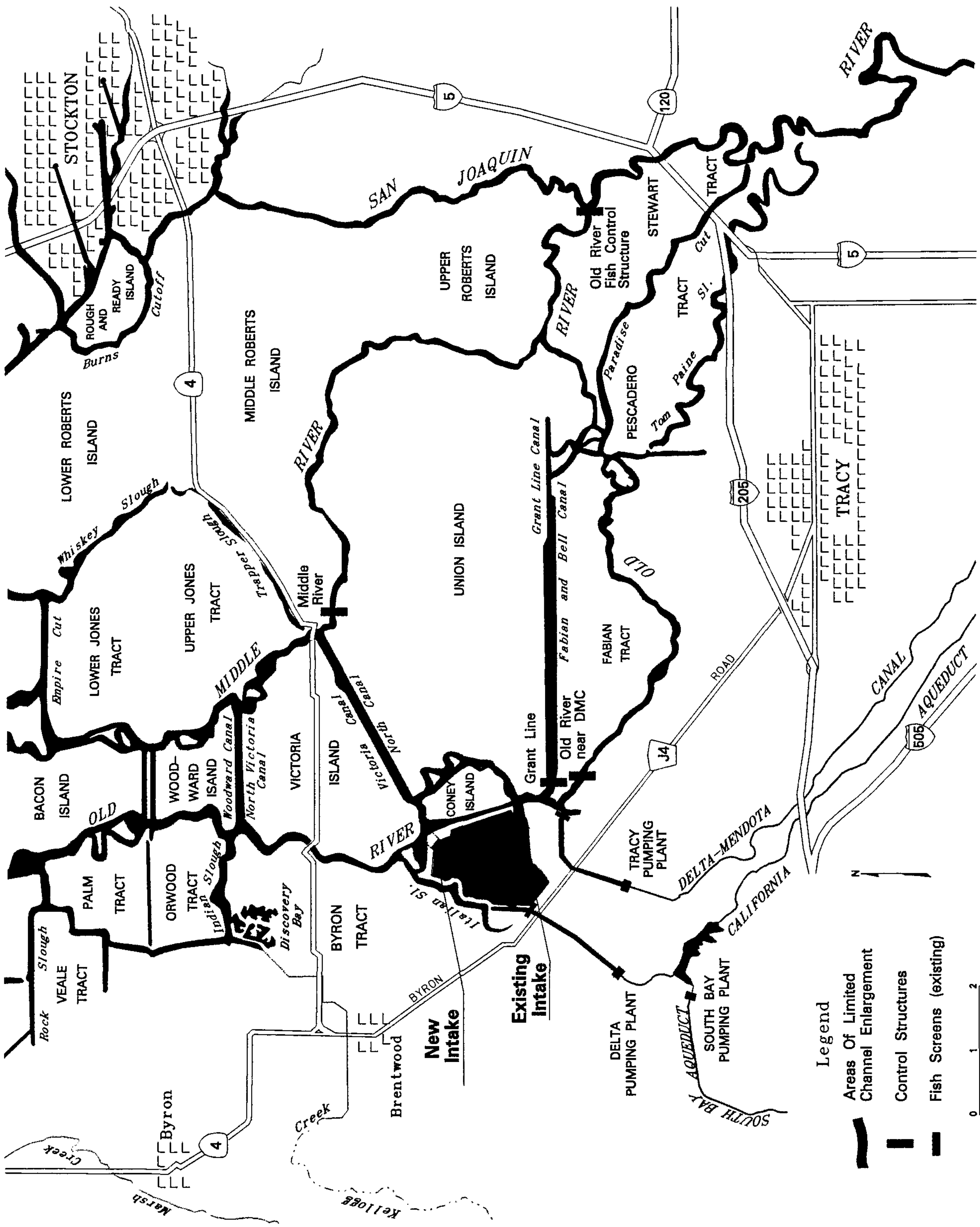
North Delta Program. Limited channel capacity in the north Delta has contributed to two major problems: reverse flow in the San Joaquin River, a consequence of SWP and CVP exports from the Delta, and repeated flooding of local leveed tracts. A proposed solution to both problems is dredging and widening of various interior Delta channels to allow more unrestricted flows. A primary focus of the North Delta Program is improving the connection to the Sacramento River, thereby sharply reducing reverse flow.

For flood control, the biggest problem in the north Delta is the bottleneck caused by the narrow channels of the Mokelumne River. Its channels are too small to handle high water flows. Repeated flooding of leveed tracts is a threat to more than 2,000 people, their homes, and thousands of acres of valuable farmlands.

The intent of the North Delta program is to allow greater flood flows to pass safely, while lowering flood levels throughout the area by dredging and building new setback levees. The new levees would provide greater protection for Thornton, Walnut Grove, Tyler Island, New Hope Tract, and other Delta lands.

Increased channel capacity and less or no reverse flow would create a more efficient means of transferring water through the north and central Delta, thus providing

Figure 10-7. Proposed Interim South Delta Water Management Program



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additional water supply for SWP users. Another benefit to increased channel capacity and reduced reverse flow is better water quality.

The winter-run 1993 biological opinion requires that the Delta Cross Channel be closed from February 1 through April 30 each year to reduce entrainment of winter-run chinook salmon into the Central Delta. Closing Delta cross channel gates increases reverse flow, thus curtailing SWP and CVP exports. Similar concerns would need to be addressed and resolved if North Delta facilities were in place.

West Delta Program. DWR is implementing a unique land use management program that could effectively control subsidence and soil erosion on Sherman and Twitchell islands, while also providing significant wildlife and waterfowl habitat. DWR and DFG have jointly developed the Wildlife Management Plan for Sherman and Twitchell islands to accomplish this objective. This plan is designed to benefit wildlife species that occupy wetland, upland, and riparian habitat, and provide recreational opportunities for hunting and wildlife viewing. Property acquired and habitat developed through DWR's contribution will be available for use as mitigation for impacts associated with ongoing DWR Delta water management programs.

This plan would significantly reduce subsidence by minimizing oxidation and erosion of the peat soils on the islands. This would be accomplished by replacing present agricultural cultivation practices with land use management practices designed to stabilize the soil. Such practices range from minimizing tillage to establishing wetland habitat.

Altering land use practices on Sherman and Twitchell islands could provide up to 13,600 acres of managed wildlife and waterfowl habitat and responds directly to the underlying need for additional wetlands in the Delta, as expressed in national and State policies for wetlands enhancement and expansion.

Agricultural Diversion Screening. Entrainment losses due to agricultural diversions in the Delta may be a substantial source of mortality for the early life stages of some Delta fish species. However, little is known about the extent of these losses or the factors affecting them. Due to concerns about water diversions and impacts on fishery resources, DWR implemented a three-year Delta Agricultural Diversion Evaluation Program in April 1992. The objectives of the program are to develop reliable data about entrainment of various fish species, determine the effects of entrainment on the species' life stages, describe the species susceptibility to agricultural diversions during the irrigation season, and compare the obtained data with information about abundance and life stages of the same species living in adjacent channels. The 1992 pilot study focused on refining sampling techniques and assessing the suitability of four diversion sites (Twitchell Island, Bacon Island, McDonald Tract, and Naglee Burk Tract). The McDonald Tract tested the effectiveness of an experimental fish screen installed on the siphon intake for the Central Delta Water Agency Fish Screen Test Project. The screen was effective in reducing entrainment of larvae 4 to 5 millimeters and larger. However, the effects of the screen impingement on the larvae are not known. Generally, larval fish are usually more abundant than juveniles or older fish due simply to the natural mortality rate of a population before they reach these later stages.

Long-Term Delta Planning Programs

Recognizing the complexity of the Delta decision-making process, the Governor provided specific direction and guidance to correct the current "broken" condition of the Delta in his 1992 statewide water policy speech. He established the Bay-Delta

Oversight Council to help guide the planning and decision-making process. BDOC is to define objectives, evaluate criteria, and formulate alternatives for the Delta. The council is composed of concerned private citizens from throughout California. BDOC will evaluate all reasonable options to solve complex Delta problems as part of this process. However, any recommended long-term solution must be practical, scientifically sound, improve protection for the Bay-Delta estuary, and provide for more reliable water supplies. The following are some of the programs that could be investigated for a long-term solution to Delta problems.

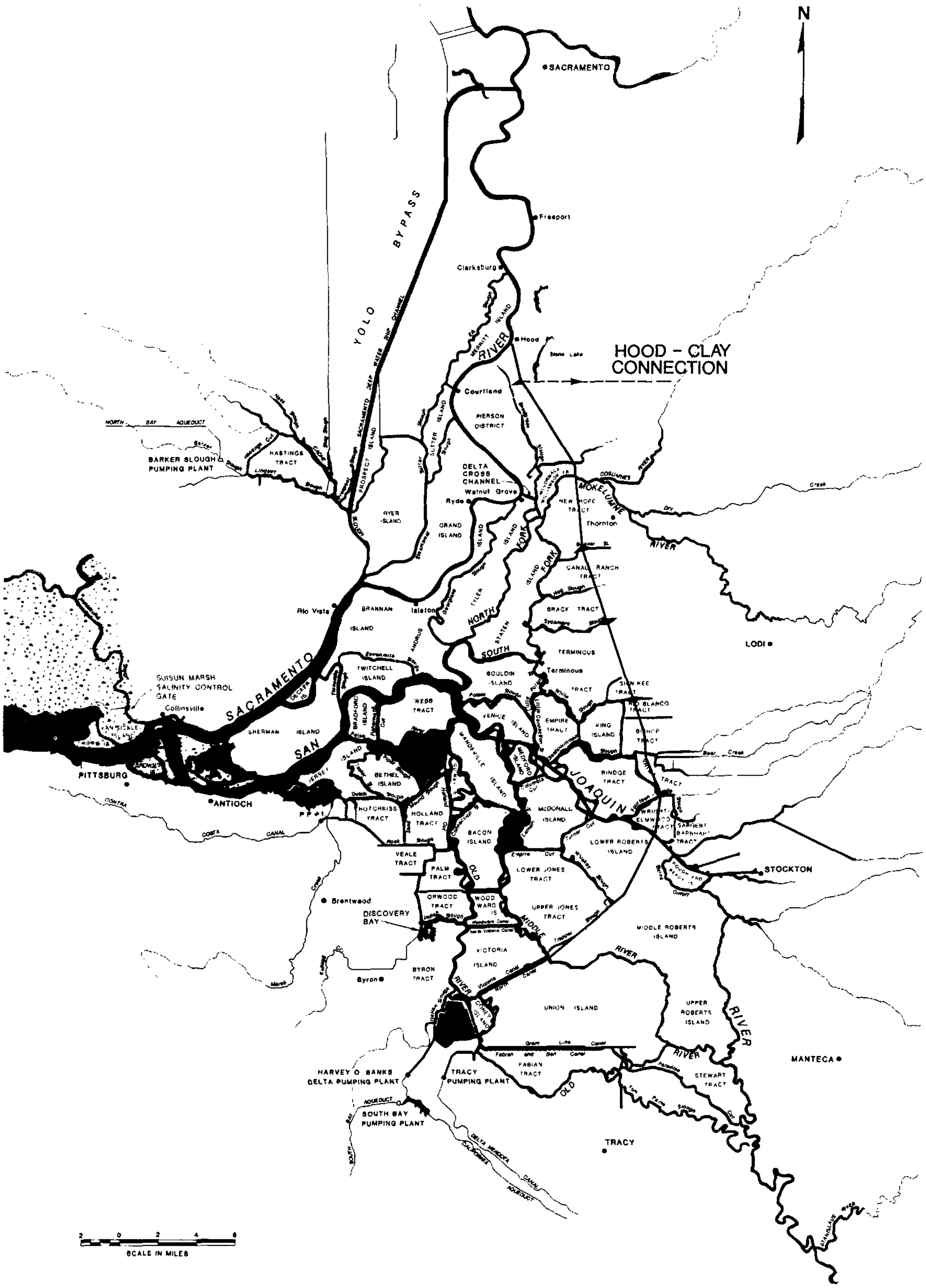
Isolated Facility. The isolated facility consists of constructing an isolated canal from near Hood on the Sacramento River to Clifton Court Forebay (with a fish screen near Hood), siphons, and the capability to release water to Delta channels to improve water circulation in Delta channels (see Figure 10-8). This option can improve water quality for urban and agricultural water users. It would eliminate reverse flow in the Delta and improve water quality and flow in the Delta by releasing water to South Delta channels. Because the intake gate of this facility would be upstream of much of the Delta along the Sacramento River, it would significantly reduce bromide and agricultural drainage impacts on water delivered to urban water purveyors. Possible collateral measures to improve water quality at the intake gate would be to divert major Sacramento Valley agricultural drainage and Sacramento Regional Treatment Plant effluent to the Yolo Bypass. This option would also reduce the effects of CVP and SWP export facilities on fish by eliminating predation in Clifton Court Forebay, improving fish migration by closing the Delta cross channel gates, and by eliminating reverse flow.

The Dual Water Transfer Facility. The dual water transfer facility would also consist of an isolated canal, with fish screens near Hood, to transfer SWP water from Hood on the Sacramento River to Clifton Court Forebay on the same alignment as the above isolated facility, except it that would be smaller. This facility would provide better quality water for urban water agencies, but its full potential, in this regard, could only be realized by separating urban from agricultural supplies using existing facilities and constructing new conveyance facilities south of the Delta. The Delta cross channel gates would remain operational. Pumping for SWP and CVP exports from the South Delta would continue, but at a lower rate and when high flows are available. Dual water transfer would allow for release of water to South Delta channels to improve water supply and circulation in the South Delta channels. This facility would provide some benefits to fisheries, but benefits would not be as great as with an isolated facility.

Sierra Source. The Sierra source option consists of a new channel transferring water directly from the Feather and Sacramento rivers, bypassing the Delta, and delivering water directly to Clifton Court Forebay and the federal export facilities in the South Delta. This option would reduce THM precursors, provide high quality water for export, and have the same fish benefit as an isolated facility. In addition, it would eliminate direct diversion along the Sacramento River and provide for a free-flowing river from Keswick through the Delta. A more detailed description of this option can be found in Chapter 11 under *Westside Sacramento Valley Project.*

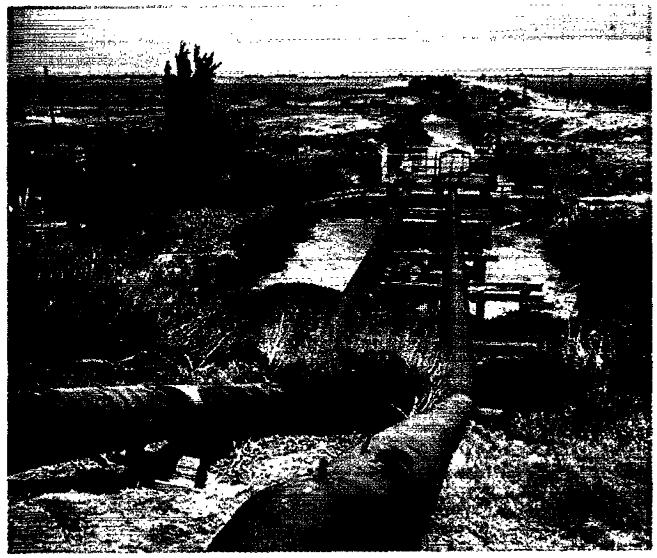
Delta Agricultural Drainage Management. This management action would collect all or a major part of the agricultural drainage from Delta islands and discharge the drainage to another location or treat it to reduce THM precursors at Delta pumps. This management program improves Delta water quality for urban use by reducing organic THM precursors; however, bromide precursors will still be present in the water. Drainage water collection and disposal could be a major undertaking that may be

Figure 10-8. Proposed Isolated Facilities (1982)



costly for the benefit gained from the program.

Delta Storage. Storage of unregulated flood flows in and around the Delta has been the subject of several studies in recent years. DWR studied Los Vaqueros Reservoir in the early 1980s to evaluate the feasibility of augmenting SWP supplies with the construction of a 1-maf storage facility on Kellogg Creek in Contra Costa County. This project has been further studied by Contra Costa Water District to provide water supply reliability to the district; see Chapter 11 for a more detailed description.



Because most agricultural land in the Delta is near or below sea level, drainage water from these areas must be pumped over levees into nearby channels or rivers. These pipes carry agricultural drainage flows from Twitchell Island, lifting the water about 20 feet and releasing it into the San Joaquin River.

In the late 1980s, a unique wetlands management and water storage project for the Sacramento-San Joaquin Delta was proposed by a land development company. The proposed project, Delta Wetlands, would convert land use on Bouldin, Webb, Holland, and Bacon islands from agricultural use to water storage and managed wetlands. Two islands, Bacon Island and Webb Tract, would be managed primarily for water storage. The stored water would be pumped from the islands to the Delta channels for sale to participating water purveyors. The other two islands, Bouldin Island and Holland Tract, would be operated primarily for wildlife benefits, which would provide an opportunity to develop new habitat for endangered species. Because the wetlands would be in a wet or semi-moist condition year-round, invertebrate food for wildlife would be more abundant. Also, nesting opportunities on Bouldin Island and Holland Tract would be greatly enhanced.

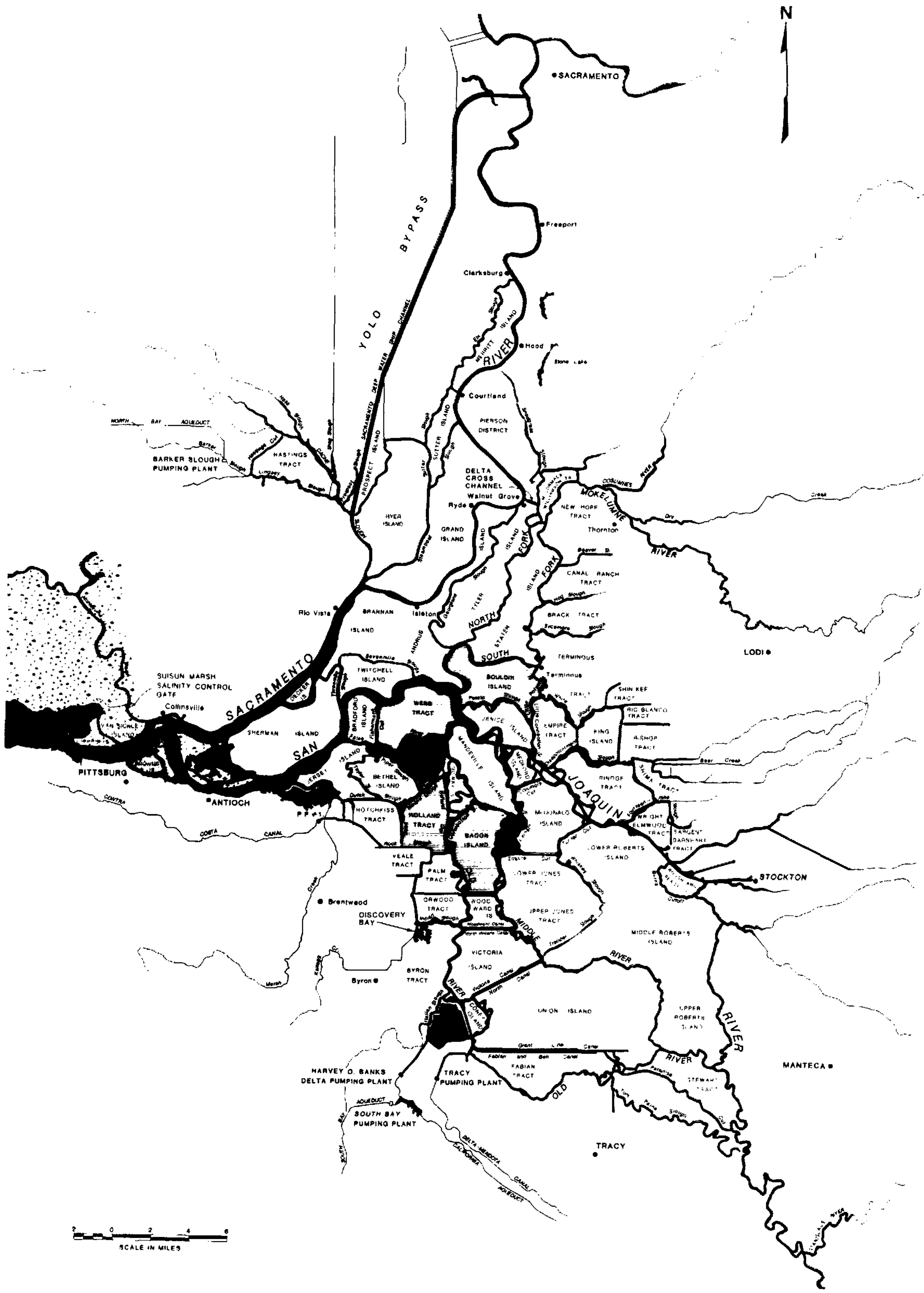
The Delta Wetlands project proposes to convert surplus wet year Delta flows to a new source of central Delta water, which would be used later in the year when demand exists (see Figure 10-9). The proposed water supply storage capacity of the project is about 230,000 af. Water rights applications have been filed for this project. The lead agencies are the SWRCB for California and the Corps of Engineers for the federal government. A Draft EIR/EIS was released on December 26, 1990. A redraft of the document is anticipated to be available in 1994.

Recommendations

The Delta is the hub of California's water supply infrastructure. It is the source from which two-thirds of the State's population and millions of acres of agricultural land receive part or all of their water supplies. The Delta provides valuable habitat and migration corridors for many species, including winter-run salmon and delta smelt, which are listed under the State and federal Endangered Species acts. Key problems in the Delta must be addressed before several other Level I options can progress to help California meet its water supply needs to the year 2020.

The Governor's water policy statement of April 1992 specifically called for taking interim actions in the Delta, such as improvements in the South Delta that will help

Figure 10-9. Proposed Delta Wetlands Project (1990)



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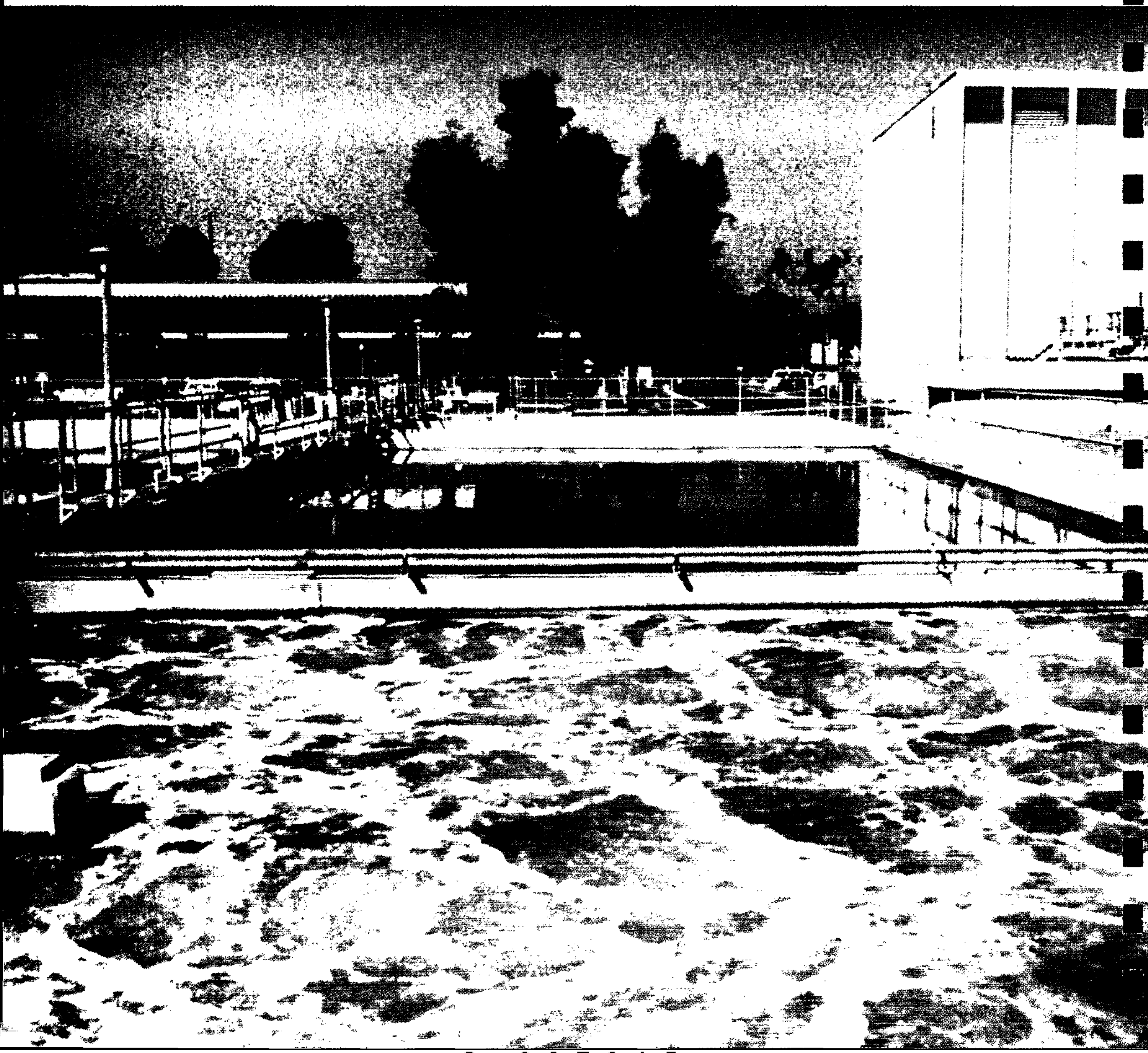
restore the environment and improve water supply in the short-term, while starting the CEQA/NEPA processes to address and develop long-term solutions to Delta problems. State and federal agencies must work together to resolve these complex issues and move toward long-term solutions.

Orange County Water District's Factory 21 has been recycling water for 16 years. The water recycling industry has made important advances in technology, allowing more efficient and less expensive reuse of water. Some of the direct uses include landscape and agricultural irrigation, industrial cooling, toilet flushing in commercial buildings, and sea water intrusion barriers.



Chapter 11

Options for Balancing Water Supply and Demand

The reliability of water supplies in each of California's ten major hydrologic regions depends on the climate, geography, patterns of water use specific to each region, the abundance of local supplies, and in some cases the availability of imported supplies. California's water supply network is a sophisticated system with many interconnections, giving local and regional water planners a wide array of options from which to meet needs. If a region cannot manage water demand through demand management actions or find sufficient water supplies within its borders, it often goes beyond those borders and imports water from, or shares water with, other regions. Conjunctive use, water banking, water marketing, conservation, water recycling, and conventional supply augmentation projects are all options that can be employed individually or collectively because of supply network flexibility.

Whenever a region looks outside of its borders for water supply augmentation, statewide water management and integrated resource planning come into the picture. Depending on the package of options chosen, one region's actions can affect another region's supplies. The statewide planning process involves assessing trends in each region's water demand and quantifying the cumulative effects of each region's demand and use patterns on statewide supplies. It basically parallels the planning process at the local and regional levels. By working through a statewide planning process, the magnitude of both intraregional and interregional effects can be analyzed. However, in a number of circumstances, measures that would be taken to manage demand, to increase supplies, and to improve water service reliability are local decisions. These decisions must weigh the cost of increased reliability with the economic, environmental, and social costs of expected shortages.

Planners at the local and regional levels face the same increasingly difficult issues that statewide planners face: the pressures of a continually growing population on existing supplies, more stringent regulatory requirements, environmental consequences of developing new sources of supply, and the increasing costs of implementing new programs or projects. To plan for long-term water supply reliability, these planners must examine an increasingly wide array of supply augmentation and demand reduction options to determine the best courses of action for meeting water service needs. Such options are generally evaluated using the water service reliability planning approach outlined below. This chapter also summarizes Level I and Level II water management options for enhancing water supply reliability.

Reliability Planning: Maintaining the Balance Between Water Supply and Demand

Water service planners now evaluate demand management options in much the same way that supply augmentation options were evaluated in traditional benefit/cost analyses completed for many of the State's existing major water supply facilities. For the California Water Plan Update, future long-term demand management options are those that go beyond the actions included in urban Best Management Practices or agricultural Efficient Water Management Practices. (See Chapters 6 and 7 for a discussion of BMPs and EWMPs.) These long-term options also go beyond retiring unproductive agricultural land. The costs of demand management or supply augmentation options to reduce the frequency and severity of shortages are now high enough that planners must also look more carefully at the costs of unreliability to make the best possible estimate of the net benefit of taking specific actions, hence the term "reliability planning." Reliability is a measure of a water service system's expected success in managing drought shortages.

The objective of reliability planning is to determine the most effective way of achieving an additional increment of reliability at the least cost and to ascertain whether the benefits, in terms of avoided shortage-related costs and losses, justify the costs of adding that increment. Reliability planning requires information about: (1) the expected frequency and severity of shortages; (2) how additional water management measures are likely to affect that frequency and severity of shortages; and (3) how available contingency measures can reduce the impact of shortages when they occur. The approach also uses information about the costs and losses associated with shortages of varying severity and duration as well as the costs of long-term and contingency water management options. Outlined below are the principles on which water service reliability planning is based:

- In any given year, available water supply and (to a lesser extent) water demand primarily depend on weather conditions. Because these conditions can be highly variable, shortages are projected in terms of their likelihood of occurrence and expected severity. In some systems, instream flow requirements, based on fish or habitat protection, can further complicate estimation of available annual supplies.
- The larger the demand, relative to supply, the more likely a shortage will occur in any given year and, given that a shortage occurs, the greater will be its expected severity.
- Historical hydrologic records provide useful information for estimating the frequency, duration, and severity of shortages under various alternative water management plans. However, hydrologic record is not a complete predictor of future events and an added measure of conservatism may be required to be consistent with water service reliability requirements for an area.
- The costs and losses associated with shortages, both economic and environmental, tend to increase at an increasing rate as shortages increase in duration and severity.
- Emergency water management actions can effectively mitigate some costs and losses during shortages, particularly if they are developed ahead of time as a part of long-term planning.
- Reliability can be enhanced by decreasing demand through reuse and conservation but at an increasing economic and, in some cases, environmental cost.
- Reliability can be enhanced by constructing desalting, reclamation, and surface or ground water storage facilities to increase supply, but at an increasing economic and environmental cost.

Plans based on these principles are more likely to achieve the best balance between the costs of increasing reliability and the benefits of reducing the frequency and severity of shortages.

Supply Reliability and Demand Variability

Surface and ground water reservoirs provide for water supply reliability through carryover storage. The success of these facilities in ensuring water availability depends on a number of factors, including storage capacity, precipitation, use in previous years, and forecasted use in future years. Use in previous years is a function of demand and decisions made by operators of the reservoir facilities. When water project planners and operators choose to restrict reservoir releases or ground water pumping to reduce the risk of shortages in the future, the cost of imposing a shortage in the current year is traded against the expected cost of future shortages. They use records of historic hydrologic conditions and trends to forecast future conditions and base their decisions about the amounts and timing of releases on these predictions.

In addition to climate, other factors that can cause water supply shortages are earthquakes, chemical spills, and energy outages at treatment and pumping facilities. Planners should also include the probability of catastrophic outages when using the reliability planning approach.

Reliability planning, used in conjunction with the Least Cost Planning process, offers water managers the best opportunity to identify how to integrate demand management and supply augmentation options into their planning process in the most productive and justifiable manner. The use of this planning process to evaluate alternative water management plans for enhancing an existing system's reliability involves the following steps:

Least-Cost Planning Process for Evaluating Water Management Plans

The least-cost planning process gives all available options an equal chance in the selection process. If any options, demand management *or* supply augmentation, are arbitrarily excluded, it becomes unlikely that the selected plan will cost the least. Using this criterion does not mean that planning decisions must be limited to evaluations that translate all costs into dollar amounts. The LCP concept can be incorporated into evaluations that rely on relative rankings of social and environmental impacts as long as the units of measurement used are consistent and the criteria for assigning values are clear. However, when social and environmental consequences of alternatives can be reasonably expressed in dollars, identifying the preferred plan will be less subjective.

With LCP, the water manager's objective becomes one of meeting all water-related needs of customers, not one restricted to looking for ways of providing additional supply. For example, if a growing service area's need for additional water can be reduced with an ultra-low-flush toilet retrofit program rather than additional water supplies, then the retrofit program should be considered on its merits and compared with all other options when putting together a water management plan.

In addition to its focus on considering all feasible options for meeting customers' needs, the LCP process requires systematic and comprehensive evaluation of all costs associated with each option when devising alternative plans, including the costs of not fully meeting the customers' needs at all times and planning for some probability of shortages. The option of planned periodic shortages must be as carefully evaluated as any other. (Plans which would result in extreme shortages jeopardizing life or health would, of course, be unreasonable.) Expressing this valuation in a way that can be used in a reliability model is often problematic. While some of the losses can be quantified (for example, the cost of lawn replacement), others, such as the loss of aesthetics, environmental cooling, and inconvenience, are difficult to measure.

1. Estimating the shortage-related costs and losses for alternative water management plans;
2. Estimating the costs of construction, operation, and maintenance for alternative water management plans;
3. Calculating point of minimum total cost (expected costs and losses from shortages plus expected cost of water management);
4. Incorporating nonmonetary social and environmental costs; and
5. Interpreting results.

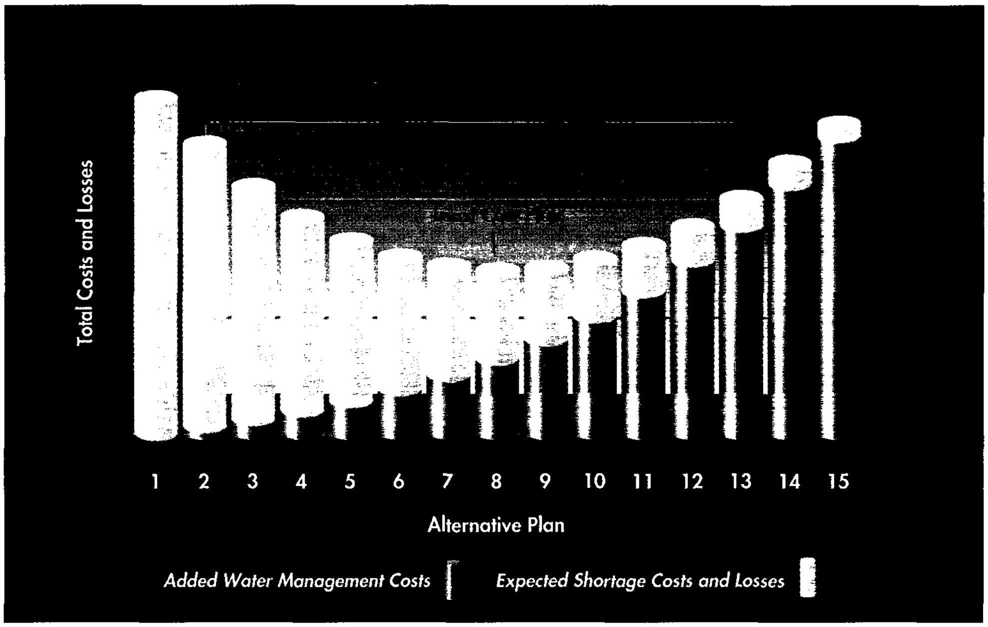
Water management programs for the SWP, the East Bay Municipal Water District, and the Metropolitan Water District of Southern California are examples of programs based on this planning process. (See the SWP and Local Water Management Programs sections under Level I Reliability Enhancement Options.)

Figure 11-1 shows the basic concept of how the alternative plans are compared, and an optimal plan for increasing water service reliability is identified. Each of the alternative water management plans that have been analyzed using the least-cost process are arrayed according to their water management costs. Plan 1 represents existing conditions (no additional water management actions). In this example, the least-cost plan is Plan 8. Water management expenditures lower than those in Plan 8 would expose the local area to higher shortage-related costs and losses than would be necessary. Water management expenditures higher than those of Plan 8 do not "pay for themselves" in terms of reduced shortage-related costs and losses.

Options for Enhancing Water Supply Reliability

California's increasing urban and environmental water needs require that existing supplies be more efficiently managed while programs are developed and implemented to provide for future water supply needs. Water management plans by State and local agencies can increase reliability through long-term or contingency measures, or both. Long-term measures reduce the expected frequency and severity of shortages, and contingency measures reduce the impacts of shortages when they occur. Three pieces of legislation were enacted to encourage agencies to develop plans

Figure 11-1. Least-Cost Reliability Planning Total Costs of Alternative Plans



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based on all available water management options: the Urban Water Management Planning Act of 1983; the Agricultural Water Management Planning Act of 1986; and the Water Shortage Contingency Planning Act of 1991. (See Chapter 2, *Institutional Framework.*) Under the auspices of these acts, DWR is working with local agencies in developing those plans.

Demand management and water supply augmentation options for meeting California's water needs to 2020 are summarized below. They are broken down into long-term and short-term demand management measures, available to water agencies to meet average and drought year needs, and long-term water supply management options. The future water management programs are presented in two levels to better reflect the status of investigations required to implement them.

- Level I options are those programs that have undergone extensive investigation and environmental analyses and are judged to have a higher likelihood of being implemented by 2020.
- Level II options are those programs that could fill the remaining gap shown in the balance between supply and urban, agricultural, and environmental water demands. These options require more extensive investigation and alternative analyses.

The following sections describe Level I options in detail; Level II options are described in general conceptual terms. The options are ordered according to whether they reduce demands or augment supplies at the statewide, regional, or local level. Options for solving complex problems in the Delta and improving Delta water quality for urban water purveyors are discussed in Chapter 10, *The Sacramento-San Joaquin Delta.*

Water Conservation Bond Laws

To assist local agencies in obtaining financing for their water management programs, California voters passed three bond laws, between 1984 and 1988, that authorized DWR to provide low-interest loans to fund project feasibility studies or construction activities. The Clean Water Bond Law of 1984 (Proposition 25) authorized $10.5 million for water conservation projects; the Water Conservation and Water Quality Bond Law of 1986 (Proposition 44) authorized $75 million for water conservation and ground water recharge projects; and the Water Conservation Bond Law of 1988 (Proposition 82) authorized $60 million for water conservation, ground water recharge, and new local water supply improvements. Although most funds for Propositions 25 and 44 have been obligated for projects throughout the State, funds are still available under Proposition 82.

Water conservation projects with loan applications certified or on file with the DWR could save an estimated 68,000 af per year. Typical water conservation projects often involve concrete lining of irrigation canals or replacing leaking water mains.

Ground water recharge projects with applications certified or on file with DWR could recharge an estimated 266,000 af per year. A Proposition 82 ground water recharge project by the Mojave Water Agency will oversize the first reach of the Morongo Basin Pipeline and use the extra capacity to provide water for recharging the aquifer beneath the Mojave River, thereby reducing the overdraft condition in the basin.

Local water supply projects with loan applications technically certified or on file with the DWR will provide 18,900 af per year. One Proposition 82 local water supply project would desalinate brackish ground water in the City of Oceanside and blend it with existing imported supplies.

Table 11-1. Level I Demand Management Options

Program	*Applied Water Reduction (1,000 AF)*	*Net Water Demand Reduction (1,000 AF)* average	drought	*Economic Unit Cost ($/AF)*[a]	*Comments*
Long-term Demand Management:					
Urban Water Conservation	1,300	900	900	315-390[b]	Urban BMPs
Agricultural Water Conservation	1,700	300	300	Not Available	Increased irrigation efficiency
Land Retirement	130	130	130	60	Retirement of land with drainage problems in west San Joaquin Valley; cost is at the Delta.
All American Canal Lining	68	68	68	—	Water conservation project; increases supply to South Coast Region
Short-term Demand Management:					
Demand Reduction	1,300	0	1,000	Not Available	Drought year supply
Land Fallowing/Short-term Water Transfers	800	0	800	125	Drought year supply; cost is at the Delta.

(a) Economic costs include capital and OMP&R costs discounted over a 50-year period at 6 percent discount rate. These costs do not include applicable transportation and treatment costs.
(b) Costs are for the ultra-low-flush toilet retrofit and residential water audit programs.

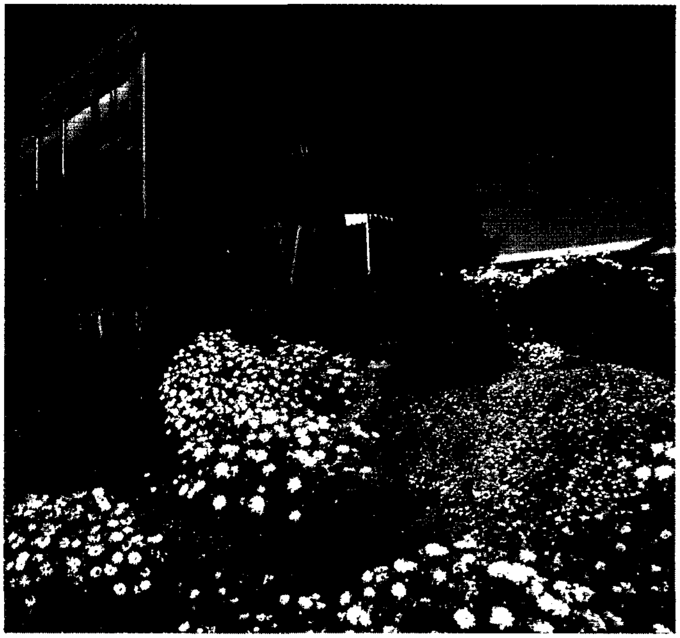
Level I—Reliability Enhancement Options

Long-Term Demand Management Options

Demand management options discussed here are water management actions designed to permanently reduce demand for water (water conservation and land retirement). Table 11-1 shows demand reductions possible from Level I demand management programs.

Water Conservation. Californians began recognizing and acting on the need for demand management through water conservation during the 1976-77 drought. Since then, much attention has been focused on plans, programs, and measures to encourage more efficient use of water. The latest of such programs are: Best Management Practices, as adopted by over 100 major urban water agencies and environmental groups, and Efficient Water Management Practices under consideration for agricultural water conservation and management. (See Chapter 6, *Urban Water Use*, or Chapter 7, *Agricultural Water Use*.) The widespread acceptance of BMPs virtually assures that they will become the industry standard for water conservation programs. As urban water costs increase, urban users will have a strong incentive to accelerate implementation of BMPs. Accepted future BMPs (measures that are accepted by urban agencies for future implementation) are expected to reduce future urban water demands by about 10 percent; this would result in an annual 1.3 maf reduction in urban applied water by 2020 and a reduction in depletions of approximately 0.9 maf. These amounts are in addition to an estimated 0.4 maf annual savings resulting from conservation measures put in place between 1980 and 1990.

Increases in agricultural water use efficiency and other EWMPs will reduce future agricultural applied water demands. These measures could result in an annual agricultural applied water reduction of about 0.7 maf by 2020 (from 1990 level), which would result in an annual depletion reduction of roughly 0.3 maf. However, it should be noted that where both surface and ground water are used, increased agricultural water use efficiency may decrease ground water recharge and thus reduce sustainable yield.



Xeriscaping is a creative way of conserving water used for landscape irrigation. Drought-tolerant plants provide shade, prevent soil erosion, and compose aesthetic designs in this xeriscape.

Water savings from conservation have been accounted for in projections of agricultural and urban water demand. New water conservation measures will undoubtedly be suggested and evaluated in the future. (See Level II options.) However, as water use continues to become more efficient, water agencies will lose some flexibility to deal with shortages during droughts.

Land Retirement. Land retirement will take place in parts of the San Joaquin Valley where drainage disposal has been a problem and where continued cultivation of some marginal lands will not be feasible. *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*, September 1990, evaluated the drainage problems in the San Joaquin Valley and recommended a plan of action to resolve the drainage problems on the west side of the valley through the year 2040. The recommendations included source control (water conservation), reuse of drainage water, and land retirement. For this water plan update, and for the purpose of agricultural water demand calculations, it was assumed that source control and land retirement recommendations would be implemented. The 1990 report suggests 45,000 acres of land on the westside of the San Joaquin Valley could be out of production by 2020 and about 70,000 acres by 2040. These amounts are accounted for in agricultural acreage projections. The net water demand reduction resulting from land retirement could be about 0.13 maf. To facilitate this option, the Central Valley Project Improvement Act provides federal authority and possible sources of funding for land retirement. At the State level, the San Joaquin Valley Drainage Relief Act provides DWR with authority to undertake a program of retiring lands with drainage problems.

Water Transfers. Year-to-year water transfers can augment a water agency's long-term annual supplies to improve the water service reliability for the receiving area. Such transfers have been going on since early this century as evidenced by the construction of several major intrastate transfer facilities described in Chapter 3. The 1987-92 drought caused some water agencies and individuals to begin looking at the potential of a water transfers market to meet water needs by augmenting long-term supplies as well as short-term drought supplies. (Long-term transfers are ones that can augment a year-to-year supply of a water-short area, while short-term drought water transfers can take place by either long-term or spot market agreements.) However, areas looking to the water transfer market for long-term supplies need an element of predictability. Uncertainties of Delta transfer capabilities now and in the foreseeable future make it difficult to predict transfer capability of the system.

The State Drought Water Bank experience was a good indication that obstacles to market-based water transfers can be overcome. However, as more and more willing buyers and sellers got together, problems in completing such deals became more apparent. In response to such problems, the California Legislature has enacted and the Governor has signed several pieces of legislation that should facilitate market-based water transfers. Additional market-based water transfer legislation continues to be introduced with the hopes of further removing impediments to such transfers. The CVPIA is an example of federal legislation that will help facilitate water transfers in California, particularly those involving federal supplies.

In some source areas of transfer supplies, such as the upper Sacramento Valley, there is concern that the health of local economies and environment are at risk if long-term water transfers are allowed. The same concerns have also been expressed in areas where the source supply is imported but is allowed to be resold in the transfer market. To address these concerns, long-term water transfers must be treated as any other water management option and be planned with a thorough investigative analysis, including alternatives, third-party impacts, and environmental documentation in accordance with CEQA. A good example of a recent long-term transfer that underwent this type of process is the long-term (permanent) year-to-year transfer of 12,700 af of State Water Project entitlement supply from Devils Den Water District, on the west side of the San Joaquin Valley, to Castaic Lake Water Agency, in the South Coast Region.

There is only one long-term water transfer agreement far enough along in its development to be considered a Level I option. This transfer would be made possible by an agreement recently negotiated between the Metropolitan Water District of Southern California and the Imperial Irrigation District. In 1988, Public Law 100-675 was enacted authorizing the lining of a portion of the All-American Canal and its Coachella branch. The act allowed the California water agencies with Colorado River water delivery contracts to fund the project in exchange for the water conserved in accordance with the provisions contained in their water delivery contracts and P.L. 100-675. USBR, Imperial Irrigation District, and MWDSC have been investigating possible alternatives for recovery of an estimated 68,000 af of seepage water through preparation of environmental documentation. In August 1993, the IID and Coachella Valley Water District boards of directors entered into an agreement with MWDSC relating to the concrete lining of 23 miles of the All-American Canal. The agreement is being negotiated among the parties. When the Secretary of the Interior issues a record of decision upon review of the final EIS/EIR, and when IID's, MWDSC's, CVWD's, and Palo Verde ID's boards approve entering into a construction funding agreement, this program can be implemented, and MWDSC's supplies could be enhanced by about 68,000 af per year.

Apart from the MWDSC-IID transfer agreement, there are no other future long-term, year-to-year water transfers far enough along in the planning process to be considered Level I options; thus, the California water budget in Chapter 12 does not include any provision for additional Level I, long-term, year-to-year water transfers. Such transfers and factors affecting their feasibility are considered as part of the Level II water management options.

Short-Term Demand Management Options

Short-term demand management options are actions taken by water managers to reduce water demand during drought. For this report, the "drought year" scenario was defined as a water year when statewide water supplies equal the average supplies of 1990 and 1991. Drought management options (mandatory conservation and land fallowing) are implemented by water managers during drought years to ensure water service reliability for critical needs during drought. Critical needs include maintaining public health and safety, providing for industrial and commercial uses, preserving permanent crops such as trees and vines, saving high-investment crops such as cut flowers and nursery products, and ensuring the survival of fish and wildlife species.

Demand Reduction. For this water plan update, a shortage of 15 percent for the urban sector during a 1990 level drought is used as a drought contingency measure. The 15-percent level reflects the actual 1990 urban water use experience for areas in California impacted by moderate shortages. It was chosen as a management planning tool for drought periods to illustrate its potential as an option rather than as an action that could impose severe hardships on affected communities. Most of the urban areas which implemented special conservation programs during the recent drought achieved cutbacks at or above this level. However, it does not mean that every type of urban water user within an area had similar cutbacks. Generally, most business users had smaller cutbacks than residential users, reflecting local water agencies' actions to avoid or minimize adverse economic and employment impacts. DWR studies indicate that some individual sectors of local economies, such as the green industry, suffered substantial income and employment losses in 1991. (The "green industry" includes nurseries, self-employed gardeners, landscapers, and landscape-related businesses.) However, from a statewide perspective, a shortage of 15 percent, based on the 1990-91 drought experience, is considered manageable at the 1990 level for drought events which would occur about once every 20 years.

As more conservation measures such as BMPs are developed and implemented in the future, a 15-percent shortage criterion will become more difficult to implement because of the increased efficiency in overall urban water use. These increases in efficiency mean that current drought contingency measures will be less productive in the future because opportunities to further reduce or eliminate water use (for example, putting displacement bags in more toilet tanks or installing more low-flow shower heads), for the most part, will have been exhausted. Consequently, smaller water supply shortages can result in greater adverse impacts. By 2020, the 1990 level of 15

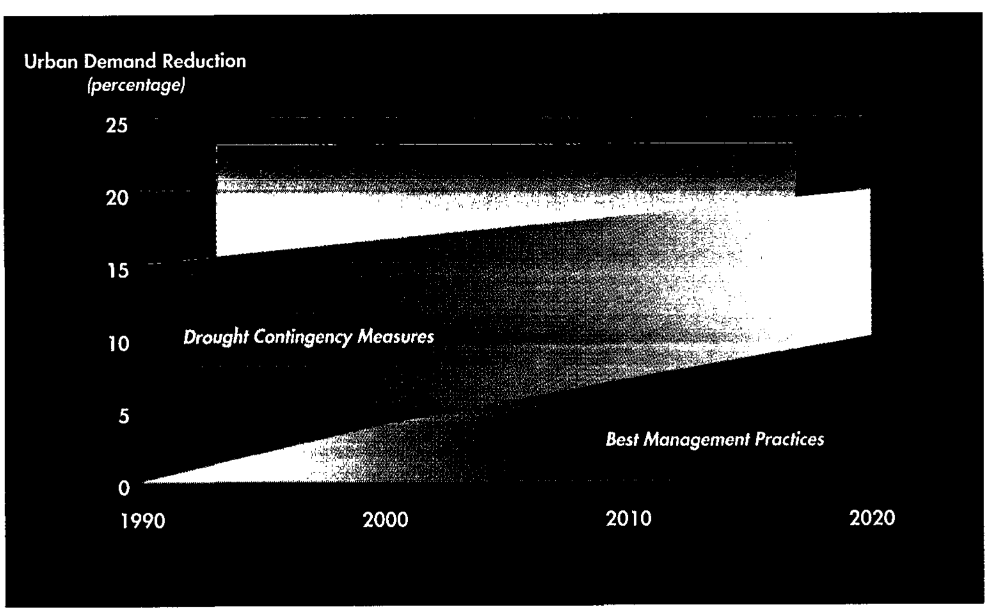


Figure 11-2. Relationship Between Drought Contingency Measures and BMPs.

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percent would be reduced to a 10-percent voluntary or mandatory shortage criterion for urban applied water use, while implementing urban BMPs would reduce water demand by 10 percent for a total demand reduction of 20 percent in 2020 during drought years. Potential future measures, such as urban rationing programs and changing water price rate structures, while not mandated by the State, are assumed to be implemented during drought periods to attain the overall 10-percent cutback.

This demand management option is considered a Level I program because it generally doesn't require extensive investigations to implement. However, many water agencies object to this being a Level I option because prudent planning already requires that agencies thoroughly investigate the costs of shortages and reduce or eliminate such shortages based on their water conservation plans, supply availability, and other relevant factors. Figure 11-2 shows the relationship between drought contingency measures and BMPs. Urban demand reductions from drought contingency measures could be about 1.2 maf in drought years by 2020. However, such programs will vary from region to region depending on each region's water service reliability needs. During less frequently occurring and more severe droughts (that is, an event that occurs once every 100 years), much greater shortages could occur, causing substantial economic impacts to urban and agricultural areas and impacts on fish and wildlife.

Short-Term Water Transfers. Short-term water transfers can be an expedient means of alleviating the most severe impacts of water shortages during drought. Such transfers generally reallocate existing supply and can enhance water service reliability in the areas receiving transfers. These transfers can be temporary transfers with short-term agreements or drought transfers with long-term agreements. Temporary transfers are generally interim supply measures taken until long-term measures can be implemented to improve water service reliability. The following sections describe short-term water transfers and potential land fallowing and water bank operations.

Table 11-2 shows major short-term transfers between water purveyors in recent years. Transfers between water projects for operational reasons are not included. Much of the transferred water was from reserve supplies or was replaced by alternative sources (such as ground water), and had little, if any, adverse economic effect on the source areas.

Some water transfers benefit fish and wildlife. Refuge managers can use water transfers to augment their supplies. Table 11-3 shows major water transfers for environmental uses in recent years.

MWDSC is looking to water conservation and land fallowing programs through long-term agreements for short-term drought transfers to increase Colorado River supplies. Through a variety of irrigation management measures, there is a potential for conservation and transfer of 0.2 maf from the Colorado River Region to the South Coast Region.

In recent years, MWDSC and other water agencies have been actively negotiating to secure additional supplies through short-term water transfer agreements to enhance reliability of their water supplies. Following are some examples of such transfers:

- MWDSC implemented a two-year test land fallowing program with Palo Verde Irrigation District beginning August 1, 1992. Under the program, 20,000 acres of agricultural land in PVID is not being irrigated with Colorado River water. MWDSC is compensating the landowners/lessees in the Palo Verde Valley who voluntarily fallow approximately 25 percent of their land. Such payments will total $25 million during the two-year period. Approximately 93,000 af of Colorado River water a year will be saved, stored in Lake Mead, and made available by the USBR to MWDSC when needed prior to the year 2000.

- MWDSC also negotiated an agreement with Areias Dairy Farms in Merced County for transfer of 35,000 af to Southern California over the next 15 years. Areias Dairy Farms would receive $175/af for water. The transfer is the first transfer under provisions of the CVPIA and requires review and approval by the Secretary of the Interior.

- MWDSC and Semitropic Water Storage District have agreed to an exchange program that basically encompasses the Semitropic local element of the Kern Water Bank. This program would allow MWDSC to temporarily store a portion of its SWP entitlements for later withdrawal and delivery to MWDSC's service area. A minimum pumpback of 40,000 to 60,000 af per year is expected and, in addition, Semitropic WSD could exchange a portion of its SWP entitlement water for MWDSC's stored water. An initial agreement to store water in 1993 has been executed and approximately 45,000 af of MWDSC's 1992 SWP carryover water was stored. MWDSC and Semitropic are currently preparing environmental documentation and completing negotiations for a long-term storage program.

- Short-term water transfers have become an increasingly significant part of water supplies for Westlands Water District. As CVP supplies to the district have decreased in recent years (primarily beginning with the 1987-92 drought and followed by reduced allocations due to operations criteria under the biological opinions for winter-run salmon and Delta smelt), the district, and water users within the district, have been looking to water transfers to augment supplies. For example, in 1993 (a wet year) when CVP supplies to the district were reduced by 50 percent, the district purchased about 129,000 af of water from a number of water agencies in the San Joaquin Valley. In addition, about 157,000 af was transferred by individual users within the district for a total of 286,700 af in 1993.

  Westlands Water District is concerned about the reliability of water available for future transfers. Generally, the district has transferred water that was surplus to the needs of the transferor (as determined by the transferor) based on water supply conditions at the time. Such transfers cannot be counted on from year to year with any degree of certainty. However, reliability can be improved to some extent by purchasing water which has a greater likelihood of being available in a dry year, such as water transferred among agencies within the San Joaquin Valley, and by long-term contracts for dry year supplies. If the district can secure a combination of long-term and temporary transfer agreements, water transfers can augment the district's supplies by as much as 100,000 af per year.

Land fallowing and water bank operations are another option under short-term water transfers during periods of drought. The State Drought Water Bank began in 1991. During the first year of operation, it purchased 820,000 af. About 50 percent of the water came from land fallowing (420,000 af), followed by ground water exchange (258,000 af) and stored water reserves (142,000 af). Operations were short-term (one-year drought supply) for areas with critical needs as determined by State Drought Water Bank criteria. Since overall statewide water supply and water service reliability was not improved for the long-term, the drought water bank is considered a contingency or drought management supply option.

Table 11-2. Short-Term Water Transfers 1982 Through 1992*

Year	Transferred From	Transferred To	Contracted Amount (acre-feet)
1982	Yuba County WA	Newhall	5,000
1984	Yuba County WA	Newhall	2,266
1985	East Bay MUD	Contra Costa WD	5,000
	USBR	DWR	12,800
1986	USBR	Grasslands	22,000
	East Bay MUD	Contra Costa WD	5,000
1987	Arvin-Edison WSD	Dudley Ridge WD	8,000
	Metropolitan Water District of Southern California	Kern County Water Agency	6,171
1988	Kern County WA	Misc. Kern	83,000
	CVP	Cawelo WD	10,000
	CVP	Lakeside IWD	10,000
	CVP	Kings County WD	10,000
	Tulare Lake BWSD	Westlands WD	1,600
	USBR	DWR	100,000
	Yuba County WA	DWR/SWP	110,000
	Yuba County WA	DWR/SWP	12,000
	Payne	Heidrick	1,450
1989	Dudley Ridge WD	San Luis WD	1,600
	USBR	DWR	10,000
	Dudley Ridge WD	Tulare Lake BWSD	2,400
	Yuba County WA	East Bay MUD	66,000
	Yuba County WA	Napa	7,000
	Yuba County WA	DWR/SWP	200,000
	Kern County WA	Westlands WD	55,000
1990	Dudley Ridge WD	Munco Farms	1,700
	La Hacienda	SWP	98,000
	Payne	Heidrick	1,450
	DWR	Sayler	8,500
	Yuba County WA	Tudor Mutual WD	6,500
	Placer County WA	Westlands WD et. al.	28,000
	East Contra Costa ID	Westlands WD	3,500
	Western Canal WD	DWR	1,500
	Yuba County WA	Feather ID	1,500
	Modesto ID	SF WD	9,000
	Yuba County WA	Napa	7,000
	Yuba County WA	DWR/SWP	146,000
	Oroville-Wyandotte ID	Westlands WD	15,000
	Placer County WA	Westlands WD	40,500
	Tulare Lake BWSD	Westlands WD	1,500
	Byron-Bethany ID	DWR	8,000
	Joint Water DB	DWR	3,000
	Placer County WA	SF WD	15,000
	Thousand Trails	Westlands WD	1,000
	Modesto ID	SF WD	9,000
1991	Mojave Water Agency	Antelope Valley-East Kern WA	1,391
	Antelope Valley-East Kern WA	Kern County Water Agency	1,000
	Placer County Water Agency	Santa Clara Valley WD	14,000
	Modesto Irrigation District	City of San Francisco	4,808
	Oroville-Wyandote ID	Westlands WD	8,500
	North Marin Water District	Marin Municipal WD	2,500

Table 11-2. Short-Term Water Transfers 1982 Through 1992* (Continued)

Year	*Transferred From*	*Transferred To*	*Contracted Amount (acre-feet)*
	State of California Drought Water Bank	various	390,945
	City of Redding	Bella Vista Water District	1,400
	Yuba County WA	Napa	7,500
	Placer County Water Agency	City of San Francisco	40,000
1992	State of California Drought Water Bank	various	134,250

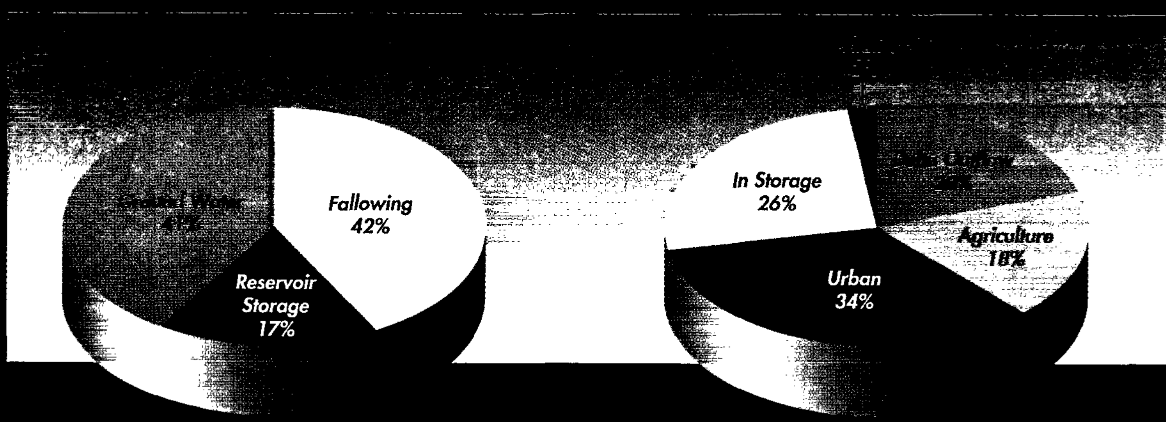
*Water transferred for environmental uses and transfers less than 1,000 AF are not included. Amounts shown are contracted amounts and actual transferred water may be less.

The Department of Water Resources is considering making the State Drought Water Bank a permanent water transfer program available for future drought management. A draft program EIR was published in January 1993, and after public review, a final EIR was released in November 1993. The EIR reports DWR's experiences in running the 1991 and 1992 drought water banks and evaluates potential environmental impacts associated with different categories of transfers. Figure 11-3 shows the categories of sources and allocations under the 1991 and 1992 drought water banks. Table 11-4 shows 1991 and 1992 drought water bank purchases and allocations. The pro-

Table 11-3. Recent Major Water Transfers for Environmental Uses
(acre-feet)

Year	*Supplier*	*Purchaser*	*Facilities Used or Facilitator*	*Use*	*Contracted Amount*
1985	USBR	DFG	DWR	Grasslands Refuge	28,000
1985	USBR	DFG	DWR	Kern National Wildlife Refuge	3,100
1986	USBR	DFG	DWR	Kern National Wildlife Refuge	4,000
1987	USBR	USFWS	DWR	Kern National Wildlife Refuge	6,100
1987	USBR	DFG	DWR	Winter Run Salmon	9,300
1988	USBR	DFG	DWR	Winter Run Salmon	125,000
1988	USBR	USFWS	DWR	Kern National Wildlife Refuge	8,200
1988	USBR	DFG	DWR	Stanislaus Salmon Spawning	45,000
1989	EBMUD	DFG	DWR	Grasslands Refuge	39,000
1989	YCWA	DFG	DWR	Sacramento-San Joaquin River Salmon Spawning and Migration	30,000
1989	USBR	USFWS	DWR	Kern National Wildlife Refuge	7,200
1990	USBR	USFWS	DWR	Kern National Wildlife Refuge	6,200
1990	WCWD	DWR	USBR	San Joaquin Wildlife Refuge	3,500
1991	USBR	USFWS	DWR	Kern National Wildlife Refuge	6,200
1991	SFWD	DFG	DWR/USBR	American River Salmon	5,920
1991	DWR	DFG	DWR	Various Wildlife Refuges	13,400
1985-91	USBR	USFWS	DWR	Kern National Wildlife Refuge	42,835
1992	BWD	DFG	DWR	Gray Lodge Wildlife Area	5,000
1992	BVID	DFG	DWR	Gray Lodge Wildlife Area	5,000
1992	MID	DFG	—	Fish and Wildlife on Merced River, Volta, Los Banos, and Mendota Areas	15,000

BVID: Browns Valley Irrigation District
BWD: Butte Water District
DWR: California Department of Water Resources
EBMUD: East Bay Municipal Utility District
MID: Merced Irrigation District
SFWD: San Francisco Water Department
USBR: U.S. Bureau of Reclamation
WCWD: Western Canal Water District



Sources of 1991 and 1992 Supplies

	1991	*1992*
Fallowing	420	0
Ground Water	258	161
Storage	142	32
TOTAL	*820*	*193*

Allocation of 1991 and 1992 Supplies

	1991	*1992*
Agriculture	83	95
Urban	307	39
Fish & Wildlife	0	25
Delta Outflow	165	34
In Storage	265	0
TOTAL	*820*	*193*

Figure 11-3. Water Sources and Allocations of the 1991 and 1992 State Drought Water Banks (thousands of acre-feet)

gram EIR only discusses a State-run drought water bank involving short-term transfers during supply shortages or drought periods over the next five to ten years. Judging from the 1991 and 1992 experience, the operation of a drought water bank in the future could probably reallocate 600,000 af of supplies during droughts.

In October 1993, the State Water Contractors negotiated a Short-Term Water Purchase Agreement with DWR to purchase options to buy 9,000 to 14,000 af of water from the San Joaquin Valley area in 1994. To minimize environmental impacts in the Delta, no water was to be purchased from sources north of the Delta. The agreement was primarily to test a process for buying and exercising options in the new climate of regulations and requirements to protect threatened aquatic species in the Delta. Due to the onset of a dry spring in 1994, the SWC requested that a direct water purchase of 73,000 af be implemented, most of it from north of the Delta. The 1994 Drought Water Bank would allow DWR to purchase water on behalf of outside agencies and SWP contractors. On June 10, 1994, DWR opened the drought water bank with those agencies as well as with SWP contractors that will have a need for 93,000 af or more.

Water Supply Management Options

Water supply management options discussed here are those actions designed to augment supply in water-short areas of California. Table 11-5 shows the capacity and annual supply for statewide and local water supply management programs possible under Level I programs.

Table 11-4. 1991 and 1992 Drought Water Bank Purchases and Allocations

1991 Drought Water Bank

Area Where Water Was Purchased	*Amount Purchased (acre-feet)*	*Agency Water Was Allocated To*	*Allocation (acre-feet)*
Above Shasta Reservoir	6,707	American Canyon WD	370
Sacramento River	73,981	City of San Francisco	50,000
Yolo Bypass	61,950	Contra Costa WD	6,717
Delta	341,819	Alameda CWC	14,800
Yuba, Feather Rivers	336,208	Alameda CFC&WCD	500
		Santa Clara VWD	19,750
		Oak Flat WD	975
		Westlands WD	13,820
		Dudley Ridge WD	13,805
		Kern County WA	53,997
		MWDSC	215,000
		Crestline-Lake Arrowhead	236
		SWP (in storage)	265,000
TOTAL	820,665		654,970

1992 Drought Water Bank

Area Where Water Was Purchased	*Amount Purchased (acre-feet)*	*Agency Water Was Allocated To*	*Allocation (acre-feet)*
Sacramento River	12,302	City of San Francisco	19,000
Yolo Bypass	42,372	Contra Costa WD	10,000
Yuba, Feather Rivers	64,419	Westside San Joaquin Valley	4,530
American River	10,000	Department of Fish and Game	24,465
Delta	2,500	Westlands WD	51,000
Stanislaus, Merced Rivers	61,705	Tulare Lake Basin WD	31,550
		Kern County WA	8,170
		MWDSC	10,000
TOTAL	193,298		158,715

SWP Water Supply Augmentation. Presented below, in addition to a discussion about SWP reliability, are several statewide programs designed to augment SWP supplies. A water conveyance project, the Coastal Branch, Phase II, is also described. The water supply benefits of these programs are included in the Level I future supplies of the SWP presented in Chapter 12. However, it must be noted that fixing the Sacramento-San Joaquin Delta is integral to any statewide water management program. More information about the Delta and available options for solving complex Delta problems are presented in Chapter 10.

SWP supply reliability under D-1485 depends on demand for water in SWP service areas and delivery capability of the project. Delivery capability of the SWP varies based on water year type.

Figure 11-4 shows the SWP delivery capability for year 2020 with existing and Level I water supply management programs under D-1485. In terms of "full service reliability," with existing facilities, the SWP will be able to meet its requirements of 4.2

Table 11-5. Level I Water Supply Management Options

Program	*Type*	*Capacity (1,000 AF)*	*Annual Supply (1,000 AF)* average	*Annual Supply (1,000 AF)* drought	*Economic Unit Cost ($/AF)*[1]	*Comments*
Statewide Water Management:						
Long-term Delta Solution	Delta Water Management Program	—	200	400	Not Available	Under study by Bay/Delta Oversight Council; water supply benefit is elimination of carriage water under D-1485.
Interim South Delta Water Management Program	South Delta Improvement	—	60	60	60	Final draft is scheduled to be released in late 1994
Los Banos Grandes Reservoir[2 & 7]	Offstream Storage	1,730[3]	250-300	260	260	Schedule now coincides with BDOC process
Kern Water Bank[7]						
Kern Fan Element	Ground Water Storage	1,000	90	140	105-155	Evaluation under way
Local Elements	Ground Water Storage	2,000	90	290	180-460	Schedule now coincides with BDOC process
Coastal Branch–Phase II (Santa Ynez Extension)	SWP Conveyance Facility	57	N/A	N/A	630-1,110	Notice of Determination was filed in July 1992; construction began in late 1993.
American River Flood Control[4]	Flood Control Storage	545[3]	—	—	—	Feasibility report and environmental documentation completed in 1991.
Local Water Management:						
Water Recycling	Reclamation	1,321	923	923	125-840	New water supply
Ground Water Reclamation	Reclamation	200	100	100	350-900	Primarily in South Coast
El Dorado County Water Agency Water Program	Diversion from South Fork American River		24	23[5]	280	Certified final Programmatic EIR identifying preferred alternative; water rights hearings, new CVP contract following EIR/EIS preparation
Los Vaqueros Reservoir-Contra-Costa Water District	Offstream Storage Emergency Supply Water Quality	100	N/A	N/A	320-950	EIR certified in October 1993, 404 permit issued in April 1994.
EBMUD	Conjunctive Use and Other Options		N/A	43	370	Final EIR certified in October 1993
New Los Padres Reservoir-MPWMD	Enlarging existing reservoir	24	22	18	410	T&E species, steelhead resources, cultural resources in Carmel River
Domenigoni Valley Reservoir-MWDSC	Offstream storage of SWP and Colorado River water, drought year supply	800	0	264	410	Final EIR certified
Inland Feeder-MWDSC	Conveyance Facilities	—	—	—	—	
San Felipe Extension-PVWA	CVP Conveyance Facility		N/A	N/A[5]	140	Capital costs only; convey 18,000 AF annually
City of San Luis Obispo-Salinas Reservoir	Enlarging existing reservoir	18	—	1.6	—	Final EIR is expected to be certified in 1994.

(1) Economic costs include capital and OMP&R costs discounted over a 50-year period at 6 percent discount rate. These costs do not include applicable transportation and treatment costs.
(2) Annual supply and unit cost figures are based on Delta water supply availability under D-1485 with an Interim South Delta Water Management Program in place.
(3) Reservoir capacity.
(4) Folsom Lake flood control reservation would return to original 0.4 MAF.
(5) Yield of this project is in part or fully comes from the CVP.
(6) N/A: Not Applicable
(7) These programs are only feasible if a Delta Water Management Program is implemented.

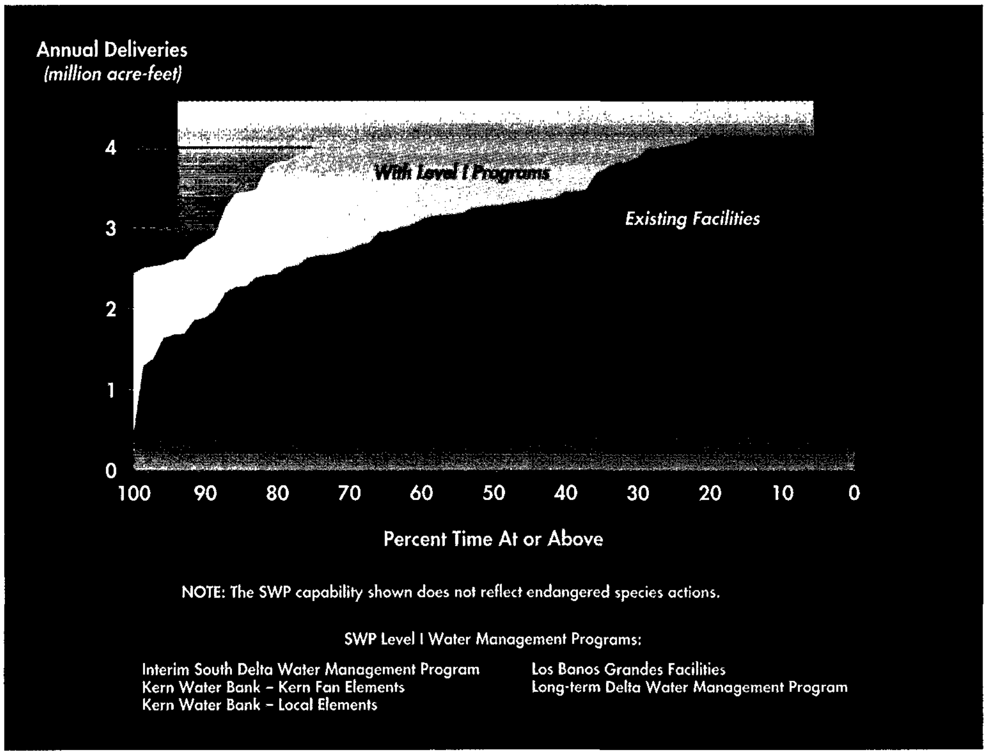


Figure 11-4. 2020 Delivery Capability of SWP with Existing Facilities and Level I Programs Based on D-1485

maf about 20 percent of the time. Planned programs under D-1485 could enable the SWP to meet its requirements about 75 percent of the time. Table 11-6 shows SWP supplies for 1990 to 2020 with and without additional Level I programs.

To illustrate the impact of drought periods on SWP deliveries to agricultural and urban users, frequency diagrams are presented showing deliveries based on a 3.2-maf level of demand for 1990 and on a 4.2-maf level of demand for 2020 (Figure 11-5). These diagrams reflect the future reliability of the SWP with existing SWP facilities and with planned Level I water management programs. These analyses are based on D-1485 standards and show that, with planned Level I water management programs,

Table 11-6. State Water Project Supplies
(millions of acre-feet)

Level of Development	SWP Delivery Capability (1)				SEP Delta Export Demand
	With Existing Facilities		With Level I Additional Programs (2)		
	average	drought	average	drought	
1990	2.8 (3)	2.1			3.0
2000	3.2	2.0	3.4	2.1	3.7
2010	3.3	2.0	3.9	3.0	4.2
2020	3.3	2.0	4.0	3.0	4.2

(1) Assumes D-1485. SWP capability is uncertain until solutions to complex Delta problems are implemented and future actions to protect aquatic species are identified. Includes SWP conveyance losses.
(2) Level I programs include South Delta Water Management Program, long-term Delta water management programs, the Kern Water Bank and Local Elements, and Los Banos Grandes Facilities.
(3) 1990 level SWP deliveries do not reflect additional supplies needed to offset the reduction of Mono and Owens basins to the South Coast Region. Reduction of Mono-Owens supplies in 1990 were offset by additional exports from the Delta to the South Coast Region.
Note: Feather River Service Area supplies are not included. FRSA average and drought supplies are 927,000 and 729,000 AF respectively.

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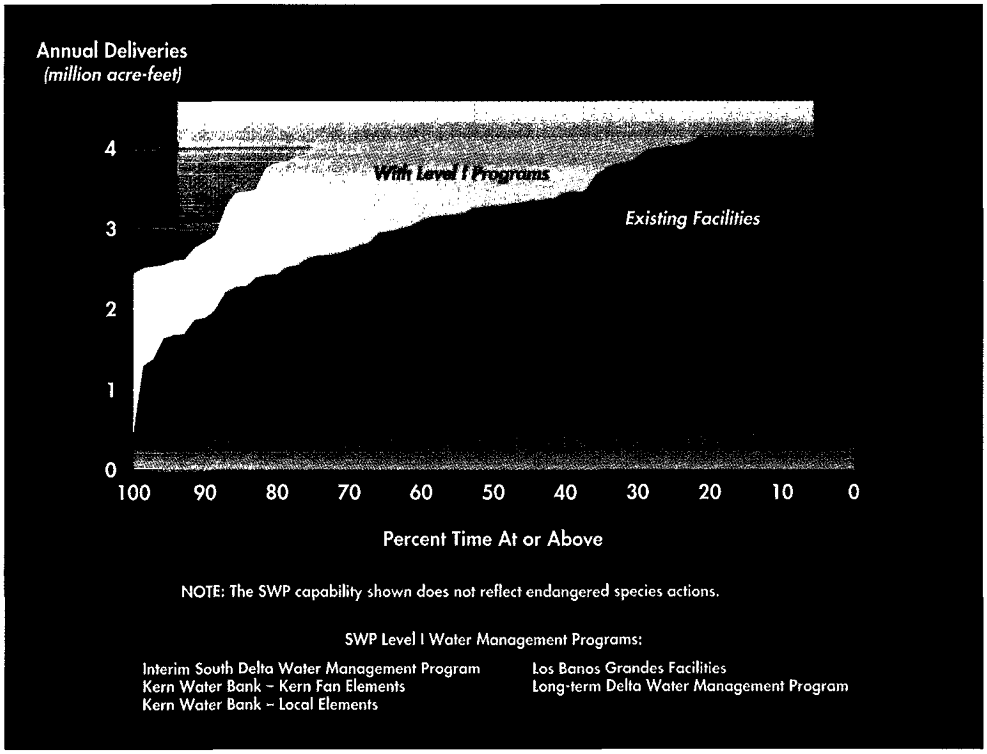

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Note: Feather River Service Area supplies are not included. FRSA average and drought supplies are 927,000 and 729,000 AF respectively.

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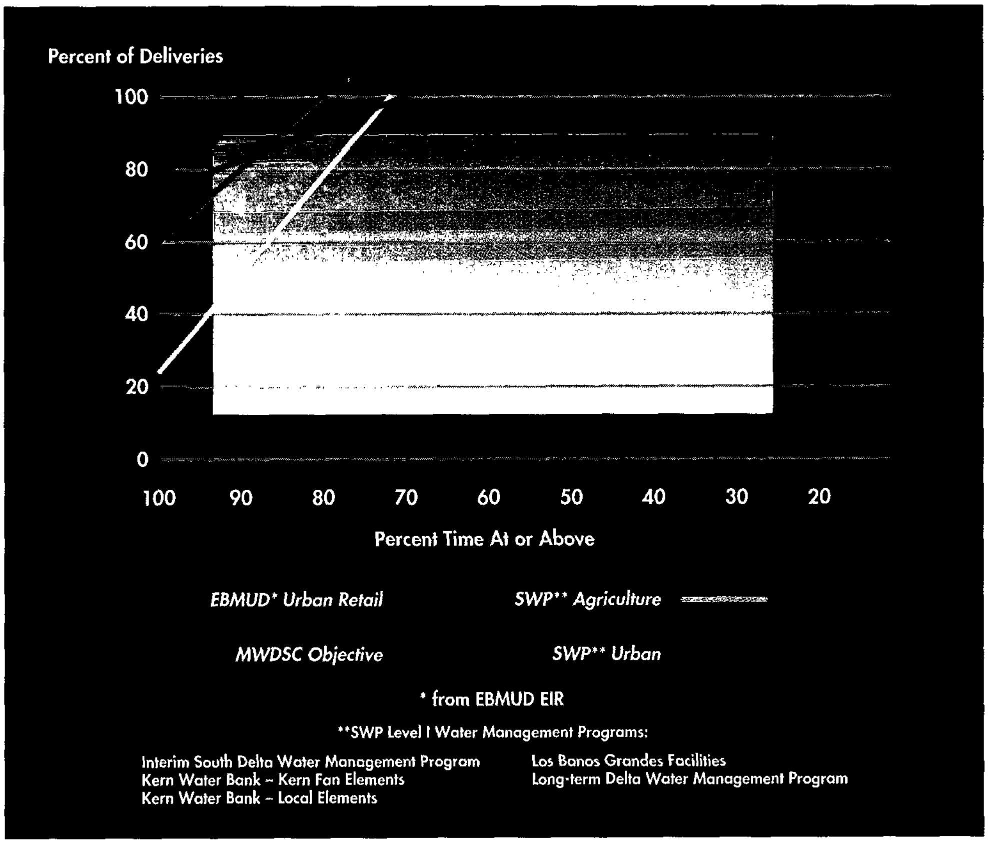


Figure 11-6. Future Delivery Capability Objectives of Various Projects

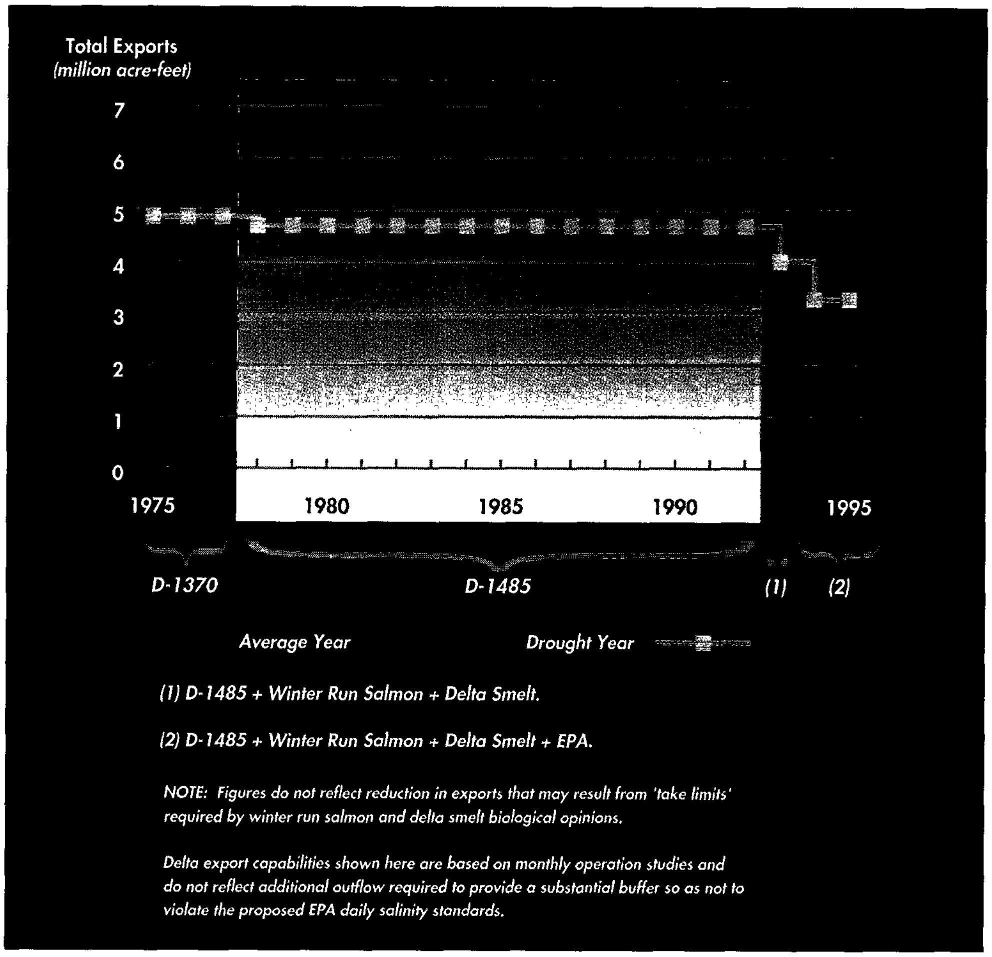
investigated to determine the most cost-effective reservoir size and its engineering, economic, and environmental feasibility. The proposed facilities would be located on Los Banos Creek in western Merced County, southwest of Los Banos and about 5 miles upstream from the existing Los Banos Detention Dam (see Figure 11-8).

Based on the feasibility investigation, a 1.73-maf reservoir was selected as a technically feasible and cost-effective solution to help offset projected future SWP water shortages and to provide the highest net benefits to the SWP. However, due to the recent endangered species actions in the Delta, the feasibility of the project is being reassessed. The actual sizing and schedule is highly dependent on the selection of a long-term solution for resolving fishery issues and facilitating efficient water transfer through the Delta.

The project will require several permits and agreements which would be issued by various agencies including a Section 404 permit (Section 404 of the federal Clean Water Act), and a Final Biological Resources Mitigation Plan being developed with DFG and the U.S. Fish and Wildlife Service, among others, to address potential impacts on biological resources.

Los Banos Grandes facilities could augment SWP supplies by about 300,000 af in average years (under D-1485). Yield of LBG in drought years would be about 260,000 af. The schedule for the investigation of this project has been slowed down in order to coincide with the Bay-Delta Oversight Council process (see Chapter 12). Financing of LBG has also been a continuing concern for several of the SWP water contractors, primarily agricultural users, who are concerned that the cost may be too high for them to pay.

Figure 11-7. CVP and SWP Delta Export Capabilities Under Various Delta Export Restrictions



The *Kern Water Bank*, established under an agreement between DWR and the Kern County Water Agency, would take advantage of available opportunities to store and extract SWP water in the Kern County ground water basin. There are eight potential elements, or separate components, to the Kern Water Bank; seven will be sponsored by local water districts and the eighth element is DWR's Kern Fan Element. DWR is awaiting the analysis of future water supply impacts that may result from a long-term solution for resolving fishery issues and facilitating efficient water transfer through the Delta. For now, the planning program is focused on completion of a Habitat Conservation Plan, incidental-take permits for terrestrial aspects of the KFE, analysis of delayed implementation on the economic viability of the KFE, and analysis of reduced levels of water supply on project economics. Once the supply impacts are identified and it appears that adequate water is available, the KFE will be reassessed, final environmental documentation will be issued, and a program for further evaluation of local elements will be considered.

The Kern Fan Element Programmatic EIR was completed in 1986. The EIR proposed acquiring up to 46,000 acres for recharging, extracting, and storing SWP water in the Kern River Fan area. DWR acquired 20,000 acres for the bank in 1988. Initial studies indicate that the Kern Fan Element could be developed to store as much as 1 maf and contribute as much as 140,000 af per year to the SWP in drought years.

The seven local elements are in various stages of investigation. A feasibility study and a negative declaration for local project impacts are essentially complete for a local

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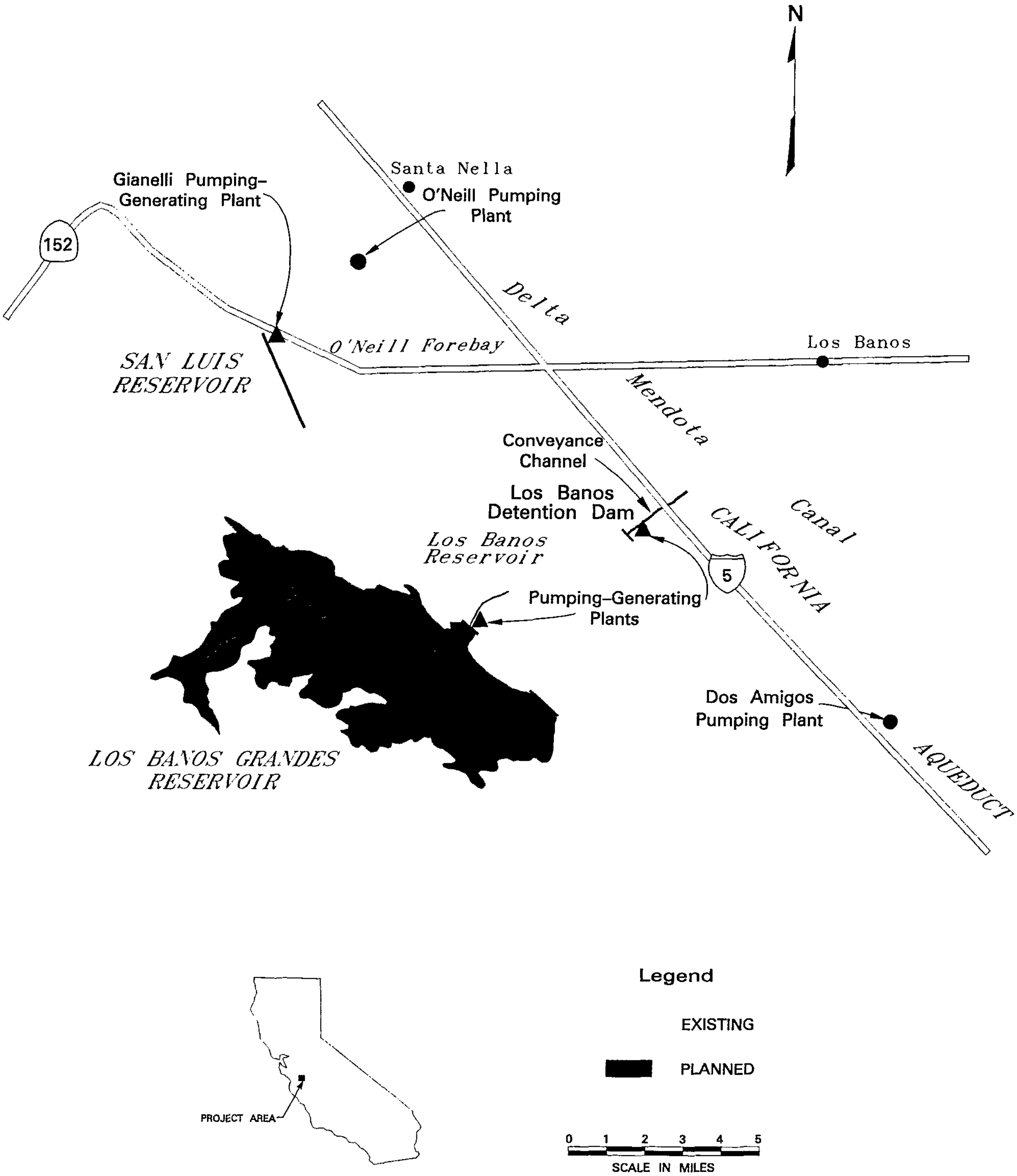
Figure 11-8. Los Banos Grandes Facilities Location



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element sponsored by the Semitropic Water Storage District. Reconnaissance-level investigations for the six remaining elements are essentially completed. These six elements are sponsored by North Kern Water Storage District, Cawelo Water District, Kern County Water Agency Improvement District Number 4, Rosedale-Rio Bravo Water Storage District, Kern Delta Water District, and (jointly) Buena Vista Water Storage District and West Kern Water Storage District.

There is considerable variation in size and potential among the local elements. With a potential ground water storage capacity of more than 900,000 af and a proposed annual recharge capacity of about 114,000 af, the Semitropic Local Element is the largest of the local elements. Cawelo Water District has the smallest element proposed to date, with a ground water storage capacity of about 110,000 af and an annual recharge capacity of about 20,000 af. Taken together, the local elements have the po-

SWP Reliability Planning Process

DWR has done substantial planning to improve the water supply reliability of the SWP. Since the mid-1980s, DWR has employed the water service reliability planning approach in the economic analyses of SWP supply augmentation programs. For this purpose, the Economic Risk Model, an urban water management simulation model, was used to identify least-cost plans by combining information about the costs and effectiveness of both contingency and long-term water management options with a method of estimating the economic costs and losses due to shortages.

For a proposed addition to the SWP, local urban water management options were first evaluated using the principle of least-cost planning to identify the optimal service area water management strategy without the proposed addition in question. The costs and losses associated with that strategy were then compared to the strategy identified as optimal under conditions with the proposed SWP additions in place. In this way, the benefits of having the proposed SWP facility in place were identified and then compared to the respective costs of those facilities.

Economic losses due to shortages were based on a contingent-value survey done for MWDSC for the SWRCB's Bay-Delta hearing process. The model was run with an SWP delivery capability sequence produced by DWR's Planning Simulation Model for each planning scenario. Weather-related changes in year-to-year urban water demand were also simulated by the ERM. The model produced "snapshots" of reliability-related costs and losses for selected future years over the planning horizon.

Using this approach, the potential contributions of all feasible local urban demand management and local supply augmentation options were explicitly taken into account on a "level playing field" in the process of estimating the benefits of the proposed SWP facilities. Local options that were the true alternatives to the proposed SWP facilities were discovered by eliminating as alternatives those local options that would be used under the least-cost planning principle irrespective of the existence of the proposed facilities. The total benefits of the proposed addition to the SWP were the avoided costs of the urban water management alternatives displaced and the reduction in costs and losses associated with a higher level of M&I water service reliability.

Under provisions of the SWP water supply contracts, when shortages in water supply occur, SWP shall reduce the water delivery to agricultural uses "not to exceed 50 percent in any one year or a total of 100 hundred percent in any series of seven consecutive years." The reductions in deliveries allowable under this provision will be made before any reduction is made in deliveries for urban uses. Increases in water demand in SWP service areas and increased environmental water demand in the Delta, as a result of actions to protect listed species, would result in more frequent and severe shortages in both future urban and agricultural supplies until new programs are implemented to augment SWP supplies.

tential to provide over 2 maf of ground water storage and a capability to store and extract about 370,000 af annually (under D-1485). When the Delta issues and their impacts on the water available for the local elements are better defined, planning investigations to examine the feasibility of the local elements of the KWB will resume.

In a 1990 demonstration program by DWR and Semitropic WSD, about 100,000 af of SWP supply was stored in the ground water basin underlying Semitropic WSD. In 1992, Semitropic WSD exchanged about 42,000 af by pumping ground water for local use and allowing a like amount of SWP entitlement water to be delivered to SWP contractors. After accounting for losses, a balance of about 50,000 af remains in ground water storage for later withdrawal. More recently, MWDSC and Semitropic WSD have agreed to an exchange program that is similar to the Semitropic element of the Kern Water Bank. This program would allow MWDSC to temporarily store a portion of its SWP entitlements for later withdrawal and delivery to MWDSC's service area, as described earlier in this chapter under *Short-Term Demand Management Options.* If MWDSC and Semitropic WSD decide to carry out a permanent and long-term water banking program, KWB local elements storage will shift from the SWP to a local MWDSC project.

Coastal Branch, Phase II. Anticipating future supplemental water supply needs, San Luis Obispo and Santa Barbara County Flood Control and Water Conservation districts signed contracts for SWP water deliveries in 1963. At the request of the two

SWP Drought Year Supply

For this water plan update, the drought year scenario is defined as a water year when statewide water supplies equal the average supplies of 1990 and 1991. For the 1990 level of development, SWP drought year supplies were estimated using the average of historical deliveries for these two years. The frequency of occurrence of such an event was evaluated by examining past hydrology and SWP delivery capabilities.

The Sacramento River Index runoff for water years 1990 and 1991 totaled 17.7 maf. A review of the index from 1906 through 1992 indicates that there have been four two-year drought periods with a two-year total runoff of 17.7 maf or less (including 1990 and 1991).

Sacramento River Index Summary of Two-Year Drought Periods
(in millions of acre-feet)

Years	Two-Year Total Runoff	Average Annual Runoff
1976-77	13.2	6.60
1991-92	17.3	8.65
1933-34	17.6	8.80
1990-91	17.7	8.85

Based on the Sacramento River Index (see Chapter 3), the frequency of the 1990-91 drought would be 4 out of 87 years, or about once every 22 years. This means the Sacramento River Index runoff for any two-year period will exceed the1990-91 runoff about 95 percent of the time.

The drought year delivery capability of a project is determined by a combination of demand, hydrology, and carryover storage in the reservoirs. For the SWP, 71-year operation studies (1922-1992) showed that the lowest two-year deliveries occurred in 1990-91 (4.4 maf), 1933-34 (4.3 maf), 1976-77 (4.0 maf), and 1977-78 (4.0 maf). This pattern indicates that the 1990-91 delivery would recur about once every 18 years.

districts, construction of Coastal Branch, Phase II, and delivery of SWP water was deferred several times until 1986, when SLOCFCWCD and SBCFCWCD asked DWR to begin planning for Coastal Branch completion.

Water demand during the 1980s exceeded dependable water supplies by an average of 60,000 af per year in Santa Barbara County and by 61,000 af per year in San Luis Obispo County. In both San Luis Obispo and Santa Barbara counties, the lowering of ground water levels has resulted in overdraft conditions and deteriorating water quality. During the recent drought a number of communities in the two counties had severe water shortages. The Phase II aqueduct is designed to deliver 4,830 af per year of SWP water to San Luis Obispo County and 42,486 af per year to Santa Barbara County.

The Coastal Branch, Phase II, is planned as a 102-mile buried pipeline which will complete the Coastal Branch of the SWP (see Figure 11-9). The existing Phase I, a 15-mile canal from the California Aqueduct to Devils Den in northwestern Kern County, was completed in 1968. Under current plans, Phase II will start at Devils Den, traverse San Luis Obispo County, extend 14 miles into Santa Barbara County, and terminate on Vandenberg Air Force Base. Three pumping plants will lift the water approximately 1,500 feet to Polonio Pass where the water will be treated at a regional treatment plant, constructed and operated by the local water purveyors. There will be a power recovery plant east of the city of San Luis Obispo. A fourth pumping plant near Casmalia will lift the water approximately 400 feet over the Casmalia Hills to Tank 5, the terminus of Phase II. From there, local facilities will convey the water 42 miles to Lake Cachuma, which serves the south coastal area of Santa Barbara County.

Potential benefits of SWP water for the area include improved municipal and industrial water quality, improved ground water quality, reduced ground water overdraft, and increased reliability of urban water supplies. While this project increases supplies in the Central Coast Region, it only reallocates existing SWP supply capabilities of the California Aqueduct.

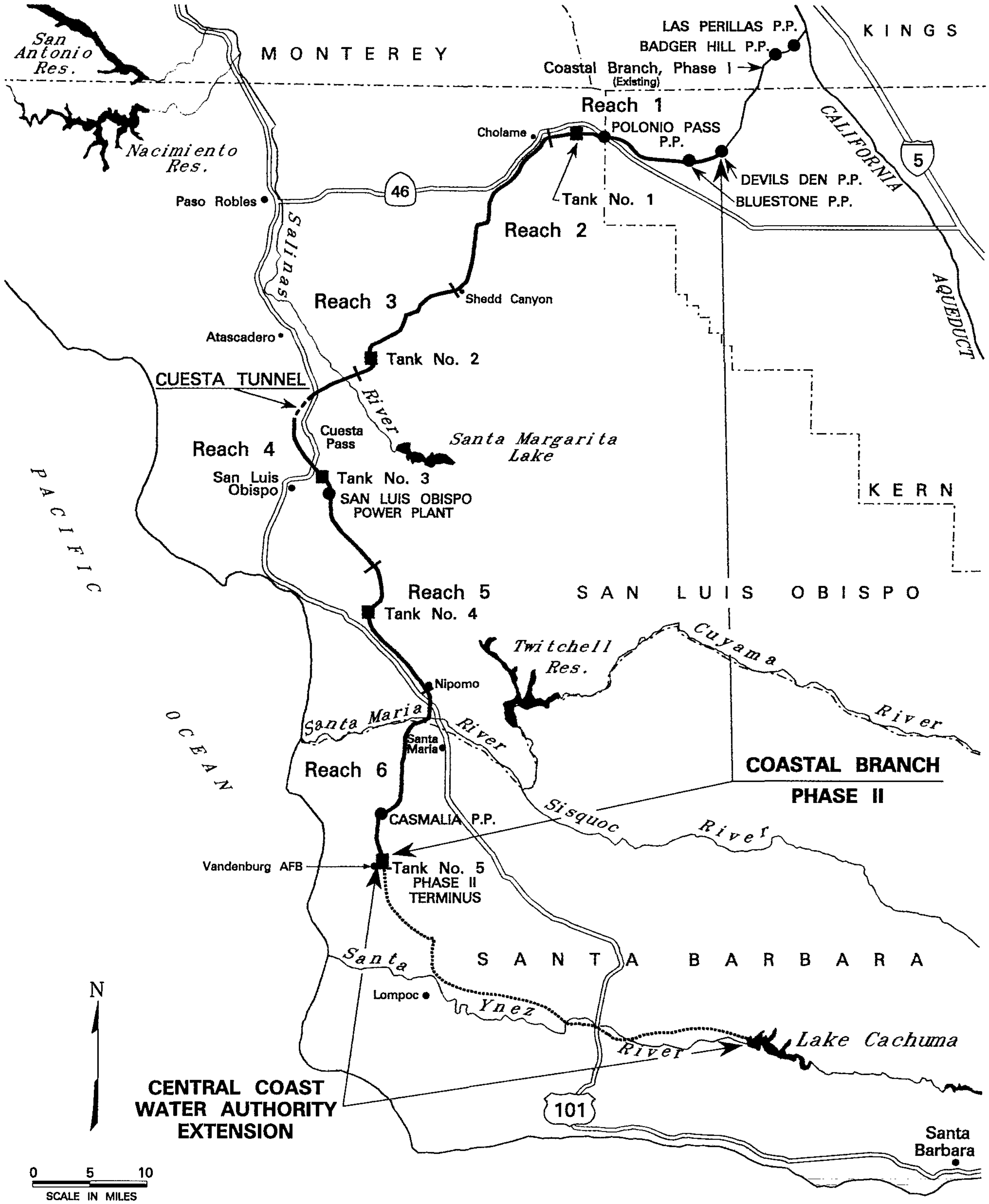
In June 1990, the Draft EIR for the Coastal Branch, Phase II, and the Mission Hills Extension (a local pipeline in Santa Barbara County) was released. The Final EIR was completed in May 1991 and the Notice of Determination was filed in July 1992. Construction began in late 1993 and is scheduled to be completed in early 1997.

CVP Supply Augmentation. Over the years, various projects have been studied for possible augmentation of CVP water supplies or improvement of water conveyance within the CVP service area. Examples include the Shasta Dam enlargement study and the San Joaquin Valley conveyance investigation described later in this chapter. Many of the CVP studies in recent years have focused on alternative strategies for managing existing water supplies, rather than development of new sources of supplies.

Recently, there has been a new mandate to investigate increasing CVP yield. The CVP Improvement Act directed the Secretary of the Interior to submit a plan to Congress by late 1995 for increasing the yield of the CVP by the amount of water dedicated for environmental purposes under the act. Methods of increasing yield can include nonstructural approaches such as water transfers and purchases, as well as structural measures such as modifications or additions to existing facilities (see CVP Level II options). The act further directs the secretary to develop and implement a plan for obtaining supplemental water supplies for fish and wildlife.

American River Flood Control (Auburn Dam). In 1991, the Army Corps of Engineers completed a Feasibility Report and environmental documentation for a

Figure 11-9. Proposed Coastal Branch Phase II and Central Coast Water Authority Extension



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545,000-af flood detention dam at the Auburn Dam site which would provide 1-in-200-year flood protection for Sacramento and vicinity. The cost of the proposed 425-foot dam, along with the proposed levee improvements in the Natomas area of Sacramento, is estimated at $700 million. These improvements would provide about $134 million of flood protection benefits annually.

Although considered by Congress, the American River Flood Control Dam (which was not a water supply augmentation project) was not authorized in 1992. Congress expressed concerns in two areas: (1) that the environmental protections being proposed by the project were not fully documented, and (2) that the guarantees offered by the project's supporters were insufficient to ensure that the dam would not impact future water supply development at the Auburn site. Studies addressing these concerns could be presented to Congress before 1996. This Level I option would have flood control benefits for the Sacramento area. Current temporary reoperation of Folsom Dam to provide limited flood control improvements has reduced the water supply available from Folsom Reservoir. Implementing this option could increase CVP supplies to the extent that Folsom Reservoir could be operated based on its original flood control criteria.

Local Water Supply Augmentation. Existing local surface water projects were among the first projects developed to meet regional water needs. Currently, in an average year local agencies provide about 11.1 maf of annual supply, including 1.0 maf of imported water supply. Future local water projects and demand management programs will also play a major role in providing water supply reliability out to 2020. Local water development programs are expected to add an additional 0.2 maf to average year supplies and 0.6 maf to drought year supplies by 2020. The following is a brief description of some local projects currently under investigation. More detailed discussions of the local projects are presented in the regional chapters of Volume II.

Water Recycling. Water recycling for the 1990 level is based on evaluation of data presented in *Water Recycling 2000*, a September 1991 report by the State Water Conservation Coalition Reclamation/Reuse Task Force, a work group of the SWRCB's Bay-Delta proceedings, and information provided by local water and sanitation districts. Projected water recycling is based on the July 1993 survey, *Future Water Recycling Potential*, by the WateReuse Association of California and input from local water and sanitation districts.

The 1993 survey indicates that there is potential for accelerating the pace of water recycling in the future. However, current budgetary problems and the economic recession have had a negative impact on water recycling project development in the State. That report indicated that the State's goal of achieving and surpassing 1 maf of water recycling by year 2010 "is definitely within reach."

Additional water supply would be generated by water recycling where the outflow of water treatment plants would otherwise enter a salt sink or the Pacific Ocean. In the Central Valley, the outflow from waste water treatment plants is put into streams and ground water basins and is generally reused. Recycling of such outflow would not generate any new supply but would be a change in the waste water treatment and use process. In coastal regions recycled water would generally be considered as new water supply. In the areas where water supply contains high total dissolved solids, such as Colorado River water, the TDS of recycled water would be too high for direct use. Recycled water with high TDS could be used if desalination techniques were employed to improve it or by blending it with high-quality water. In the South Coast Region local water agencies are concerned that the lack of future adequate high-quality water for blending supplies or the cost of desalination of recycled water could affect the timing of future water recycling facilities by delaying their cost effective implementation until adequate good quality source water is available.

To estimate how much additional supply would be generated by Level I and Level II water recycling, a set of criteria was established. Total annual Level I water recycling for 2020 is projected to be about 1,321,000 af. This would contribute about 923,000 af of new water to the State Water Project supply. Table 11-7 shows 1990 and projections of total water recycling and new water supply by hydrologic region.

Ground Water Reclamation. High total dissolved solids and nitrate levels are the most common ground water quality problems. Ground water reclamation programs are designed to recover this degraded ground water. Currently, most of the ground water reclamation programs under consideration are located in Southern California (excluding ground water reclamation solely to remediate contamination at hazardous waste sites). Some of the polluted water must be treated, some can be blended with fresh water to meet water quality standards, and some can be applied untreated for landscape irrigation. Total annual contribution of ground water reclamation by year 2000 is about 90,000 af and is accounted for in evaluations of the South Coast Region's ground water supply.

El Dorado County Water Agency Water Program. The El Dorado County Water Agency is preparing a water resources development and management plan to meet the long-term needs of the local water districts within its jurisdiction. In May 1993, EDC-

Criteria for Determining Level I and Level II Water Reclamation and Available Supplies for Bulletin 160-93

1. Additional water supplies resulting from recycled water occur where the existing outflow from a waste water treatment plant is directly discharged to a salt sink or the Pacific Ocean. These supplies were counted as new water supplies. In other areas, reuse of existing agricultural drainage and waste water treatment outflow already occurs and thus recycling of this water will not add to the State's overall water supplies. For example, outflow from waste water treatment plants in the Central Valley is generally put into streams or ground water basins and is reused. Recycling of such outflow does not generate new supply but would be a change in the waste water treatment and use process. Therefore, recycling in this area of the State will not contribute additional supplies for the State. An exception is in the westside of the Tulare Lake Region where outflow from treatment plants could be lost to a salt sink (such as unusable ground water) without any reuse.
2. Recycled water added to a coastal stream for environmental enhancement was counted as both a supply and an environmental demand.
3. Recycled water used for ground water recharge for ocean salinity barriers in coastal basins was not counted as a supply because, in general, it prevents further degradation of the existing ground water supply rather than adding new supply. Recycled water used within the treatment plants was not counted as a supply.
4. Future water recycling: for Bulletin 160-93, the total future water recycling was based on the WateReuse Association's 1993 survey and is divided into Level I and Level II facilities as follows: Level I water recycling projects are projects that are moving forward after having undergone extensive investigation and have a 75 percent or greater likelihood of being implemented; Level II water recycling projects are the remaining projects.

Table 11-7. Total Water Recycling and Resulting New Water Supply by Hydrologic Region
(thousands of acre-feet)

Hydrologic Region	1990 Total Water Recycling	1990 New Water Supply	2000 Total Water Recycling	2000 New Water Supply	2010 Total Water Recycling	2010 New Water Supply	2020 Total Water Recycling	2020 New Water Supply
North Coast								
Existing	14	11	—	—	—	—	—	—
Level I	—	—	23	14	23	17	23	20
Level II	—	—	2	2	4	4	6	6
San Francisco Bay								
Existing	36	36	—	—	—	—	—	—
Level I	—	—	74	74	111	111	119	119
Level II	—	—	20	20	40	40	59	59
Central Coast								
Existing	40	15	—	—	—	—	—	—
Level I	—	—	74	59	87	70	87	70
Level II	—	—	0	0	0	0	0	0
South Coast								
Existing	140	82	—	—	—	—	—	—
Level I	—	—	632	481	814	580	888	679
Level II	—	—	110	110	246	246	302	302
Sacramento River								
Existing	9	0	—	—	—	—	—	—
Level I	—	—	10	0	11	0	11	0
Level II	—	—	0	0	0	0	0	0
San Joaquin River								
Existing	24	0	—	—	—	—	—	—
Level I	—	—	30	0	35	0	48	0
Level II	—	—	0	0	0	0	0	0
Tulare Lake								
Existing	63	0	—	—	—	—	—	—
Level I	—	—	68	0	73	0	80	0
Level II	—	—	0	0	0	0	0	0
North Lahontan								
Existing	8	8	—	—	—	—	—	—
Level I	—	—	8	8	8	8	8	8
Level II	—	—	1	1	1	1	1	1
South Lahontan								
Existing	13	13	—	—	—	—	—	—
Level I	—	—	13	13	14	14	14	14
Level II	—	—	1	1	1	1	2	2
Colorado River								
Existing	7	7	—	—	—	—	—	—
Level I	—	—	26	9	37	12	43	13
Level II	—	—	0	0	0	0	0	0
TOTAL								
Existing	354	172	—	—	—	—	—	—
Level I	—	—	958	658	1,213	812	1,321	923
Level II	—	—	134	134	292	292	370	370

WA certified a final Water Program EIR for the El Dorado Irrigation District Service Area.

Water demand for the EID service area is projected to increase from a 1990 level of 34,000 af to 60,000 af in 2020. EDCWA proposes to provide a long-term water supply to the EID service area by implementing a water management program that involves use of various combinations of water rights, water storage, and water conveyance facilities. The preferred alternative is a combination of the El Dorado Project, the Folsom Reservoir Project, the White Rock Project, and a diversion and conveyance project which would not provide any additional water supply. The El Dorado Project consists of securing water rights to certain direct diversion and storage amounts from the South Fork of the American River using PG&E's El Dorado Canal. The combined average supply from these rights could be up to 17,000 af per year.

The Folsom Reservoir Project involves recently enacted federal legislation (PL 101-514) designating 15,000 af of water stored in the CVP's Folsom Reservoir for municipal and industrial supply for EDCWA. EDCWA proposes to make this water supply available to both EID and Georgetown Divide Public Utility District. EID's portion of the Folsom Reservoir would be about 7,000 af and 6,000 af for average and drought years, respectively.

Other alternatives considered involve the construction of new dams and reservoirs. Such options would be more costly and involve greater environmental impacts. To a certain extent, the EDCWA approach relied on least-cost planning concepts, in that both structural and nonstructural options were evaluated on an equal basis.

Contra Costa Water District—Los Vaqueros Project. Water quality and reliability are the objectives of Contra Costa Water District's Los Vaqueros Project. The Environmental Impact Report for this $450-million project was certified in October 1993, and in April 1994, the Army Corps of Engineers issued a permit for the project under Section 404 of the Clean Water Act. The 100,000-af offstream reservoir near Byron would store high-quality Delta water during wet periods for blending with lesser quality Delta supplies in dry seasons. The reservoir is also designed to meet the district's need for storage in the event of an emergency, such as a temporary loss of Delta supplies.

The project includes a new supplemental Delta intake location, and conveyance and storage facilities necessary for project operations. The proposed reservoir would inundate about 1,400 acres along Kellogg Creek. The district purchased about 20,000 acres in the canyon along the creek, which would be used for open space and protected from future development. Careful land management would improve habitats for some rare and endangered species in the canyon. The Los Vaqueros Project would improve the reliability of the district's supplies but would not add any new water, as water for the project is provided by the CVP under an existing contract.

East Bay Municipal Utility District Water Supply Management Program. The East Bay Municipal Utility District is a multipurpose regional agency with water supply as a major function, serving an estimated 1.2 million people and industrial, commercial, and institutional water users in the East Bay region of the San Francisco Bay Area.

EBMUD forecasts its customer demand to increase from an average 1990 level of 246,000 af to 280,000 af in 2020. This projection includes demand reductions as a result of additional conservation and reclamation programs. It is projected that increased use of Mokelumne River water by senior water rights holders will decrease availability of Mokelumne River supply for EBMUD. With increases in customer demand and the projected increased use by senior water rights holders, and possible

EBMUD Reliability Planning Process

The source for 95 percent of EBMUD's supply is the Mokelumne River in the Sierra Nevada, with a diversion point at Pardee Reservoir in the foothills. This reservoir is used in conjunction with Camanche Reservoir, immediately downstream of Pardee, and with five smaller terminal reservoirs in the East Bay Service Area.

Reservoir storage is used to meet EBMUD's needs for service area water supply reliability and downstream obligations, including releases for irrigation, streamflow regulation, flood control, fishery needs, and the senior water rights of riparian and other appropriative entitlements. The existing storage capacity is vital to the district's ability to meet its obligations, to provide reliable service to its customers, and to provide water for instream uses in dry years.

In wet years, any portion of the district's water right entitlement that is not directly diverted for current use in the district's service area, or diverted to storage in Pardee or Camanche reservoirs, continues to flow downstream and is no longer available to the district. In dry years, the runoff is less than needed to meet demand and the district must use storage from prior years. In extended critically dry periods, the existing storage capacity on the Mokelumne River is not sufficient to supply all consumptive and instream needs.

Approach Used to Analyze Water Service Reliability. The analysis of water supply begins by defining each of the supply, demand, and operational factors affecting EBMUD's need for water (see Figure E-1). The specific conditions, or assumptions, associated with each factor affecting the need for water are then defined.

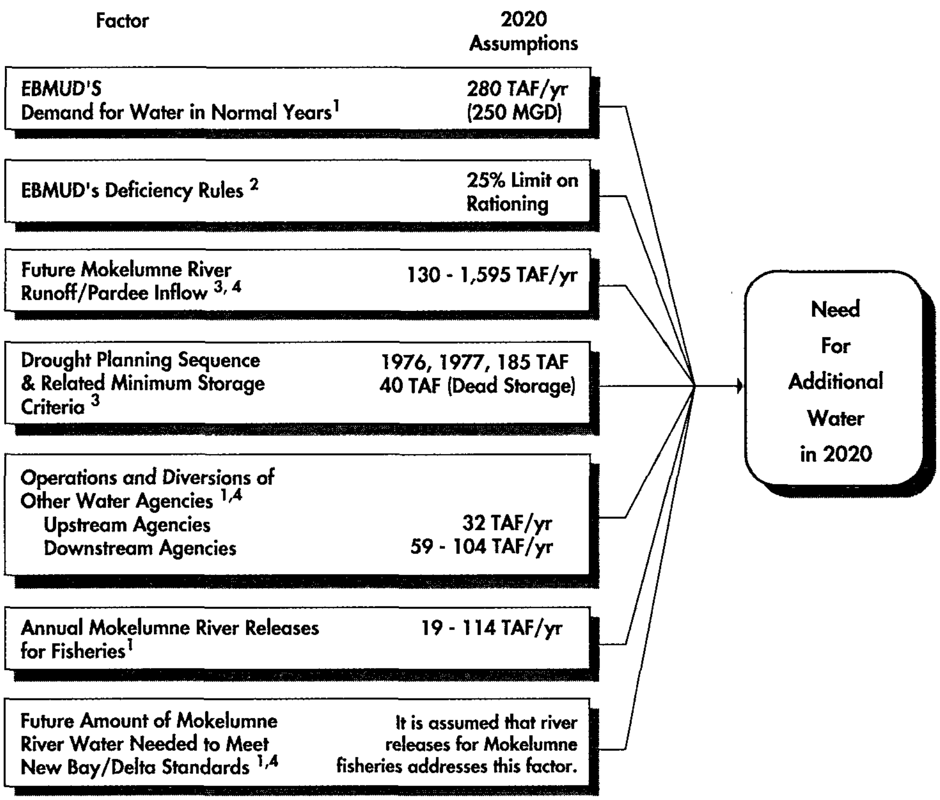
The combined effects of each of the factors affecting the need for water and the related assumptions were analyzed using the district's water supply planning computer model. The water balance model of Mokelumne River operations allows for the simultaneous consideration of many interrelated factors. The model is used as a water supply planning tool by estimating reservoir storage levels, river flow rates, deliveries to customers, shortages, and hydroelectric generation for the next year and over the 70-year Mokelumne River study period under various conditions.

As a matter of policy, EBMUD uses a three-year "worst-case" scenario as its drought planning sequence. It assumes the historical 1976-77 sequence plus a third year which is the hydrologic mean of the previous two. During prolonged dry periods, such as the drought planning sequence, EBMUD imposes deficiencies (rationing) on customers based on rules which use the projected storage at the end of September. By applying these deficiencies in the early years of a drought ("early deficiencies"), EBMUD attempts to minimize rationing in subsequent years if a drought persists while continuing to meet its current and subsequent year fish-release requirements and obligations to downstream agencies.

The deficiency rules are used to achieve the system-wide annualized demand reduction target of no more than 25 percent. The limit of 25 percent was adopted by the EBMUD Board of Directors as a reasonable planning criterion in 1989. Although the impacts of shortage were not evaluated in terms of overall economic costs and losses, general impact studies by user type for various levels of shortage have been done by EBMUD. If the decision is made to do the additional work necessary to balance the total costs of reliability enhancement against the reduction in total shortage-related economic costs and losses, the framework to do this exists.

The 25-percent criterion is an overall use reduction target which will result in an estimated 31-percent reduction to residential users, a 25-percent reduction to commercial and institutional users, and a 10-percent reduction to most industrial users. The higher reduction experienced by the residential users is the result of an exemption process during shortage events which has as a major goal the protection of the economic well-being of commercial and industrial firms and the area's economic health.

Figure E – 1. Factors Used by EBMUD in Projecting the Need for Water



Notes:
1 Conditions adding to the District's need for water
2 *Conditions reducing the District's need for water*
3 Conditions which could add to or reduce the District's need for water
4 Conditions largely outside District's control

TAF/yr = thousand acre-feet per year
MGD = million gallons per day

Source: EDAW, Inc., and EBMUD

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EBMUD Reliability Planning Process (continued)

Long-Term Management Options and Reliability. In February 1990, EBMUD began formal preparation of an Updated Water Supply Management Program. The Updated WSMP addresses an extensive range of alternatives to help meet EBMUD's 2020 water needs. Alternatives include reducing demand on the Mokelumne supply through conservation and reclamation (the use of recycled water) and augmenting supplies through ground water storage/conjunctive use, reservoir storage, and supplemental supply.

A thorough alternatives screening process, including the use of the district's water supply planning model by EBMUD, reduced the range of alternatives within each of the component categories based on evaluation using the district's planning objectives and related screening criteria. The district's planning objectives and screening criteria are very comprehensive and cover a broad array of issues. These are organized into the the following categories: operational, engineering, legal, and institutional; economic; public health, public safety, and sociocultural; and biological.

The surviving component alternatives were then used to develop alternative Composite Programs, or groups of demand-reduction and supply components that together would provide EBMUD with an adequate water supply based on the water supply reliability analysis described earlier in this chapter. Six Composite Programs were identified to represent a reasonable range of alternatives. (See table 1.)

Assumptions, including EBMUD'S demand and physical system characteristics, operating practices and criteria, water supply demands of the agencies, fishery releases, flood control requirements, and releases for channel losses were evaluated in operation studies and included in updated water supply management programs. WSMP is discussed in detail under Level I—Reliability Enhancement Options. Any short-term or long-term need for additional water is determined by using water system model runs to estimate projected shortages during upcoming months or EBMUD's drought planning sequence. Figure 2 shows the results of making model runs for three planning scenarios: existing conditions, 2020 conditions with no water management planning actions, and 2020 conditions with proposed increased fishery flows under the EBMUD Lower Mokelumne River Management Plan. The increases in shortage frequency and magnitude can be clearly seen.

Table E-1. Primary Composite Programs for EBMUD

Primary Composite Programs \ Components		DMP	Conservation (Savings)[1]		Reclamation (Savings)[1]			Groundwater			Reservoir	Supplemental Supply		Aqueduct Security	LMRMP	Composite Program Screening Designation[3]
		Maximum Deficiency[2]	II (13 MGD)	IV (35 MGD)	A1 (8 MGD)	A2 (21 MGD)	A6 (8 MGD)	Agricultural Exchange	River Substitution	Direct to Aqueducts	Raise Pardee +150 TAF	Delta	Folsom South Connection			
I	Demand-Side Management	35%		●		●	●							●	●	X
II	Groundwater	25%	●		●			●	●	●		●		●	●	A'
III	Delta Supply	25%	●		●								●	●	●	B'
IV	Groundwater and Folsom South Connection	25%	●		●			●	●	●				●	●	C
V	Raise Pardee	25%	●		●						●			●	●	F
VI	Groundwater Only (Least Cost)	25%						●	●	●				●	●	J

Notes:

1 Savings indicated are in addition to savings from existing and adopted conservation and reclamation programs. Combining conservation and reclamation is not necessarily additive due to overlapping.

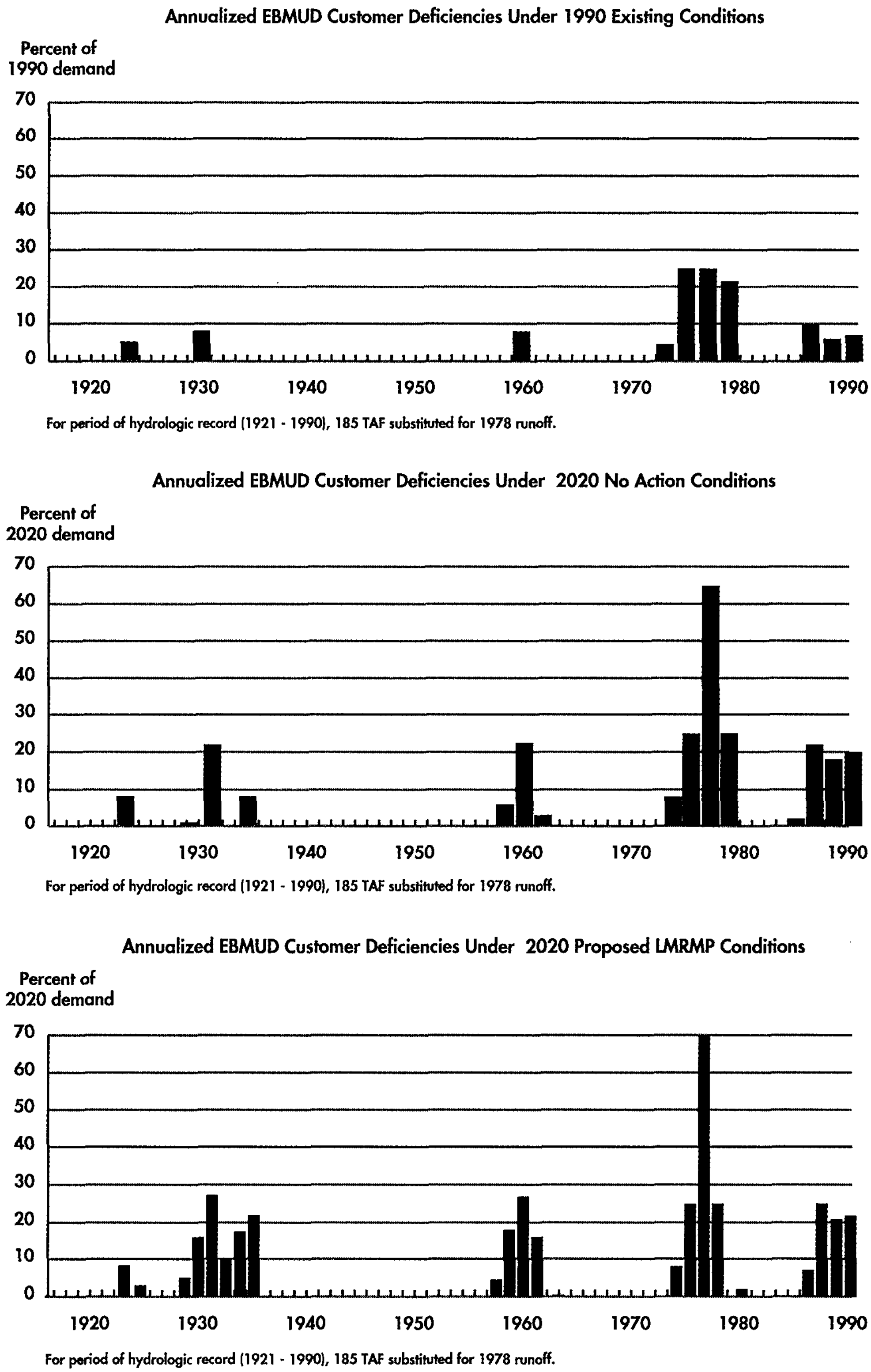
2 Drought Management Programs (DMP) are short-term rationing or demand deficiencies imposed on customers during droughts. A DMP is used in addition to some level of conservation.

3 During screening of alternative composite programs, the alternatives were identified by these letters.

Source: EDAW, Inc.

● Components included in Primary Composite Programs

Figure E – 2. Projected EBMUD Customer Deficiencies



Source: EBMUD

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additional Mokelumne River fishery flow requirements, EBMUD projects a drought year shortage of 130,000 af per year by 2020. To address this deficiency, EBMUD has been studying a wide range of potential water management options to help meet its future water demands. These include: several additional conservation programs, water recycling programs, conjunctive use options on the lower Mokelumne River, use of its CVP contract for Folsom-South Canal water, and raising the height of Pardee Dam.

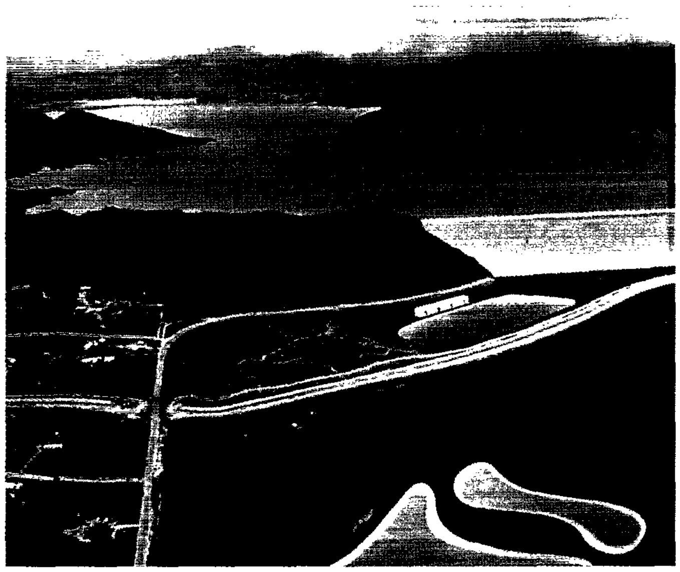
After several hearings and extensive evaluation, EBMUD's Board of Directors designated two of the six composite programs as preferred alternatives. The main element of each alternative is the use of ground water storage. One of the preferred alternatives (Alternative II) would store available surface water in an underground basin during wet years. During dry years, this water would either be: (1) used for agricultural irrigation in the lower Mokelumne River basin; or (2) pumped into aqueducts for use by EBMUD's customers. The conjunctive use element of this program would require cooperation of San Joaquin County where ground water storage is located. The other preferred alternative (Alternative IV) includes the same components mentioned above, plus a supplemental water supply from the American River. Rights to use of this supply are regulated by court order. American River water could be delivered to the Mokelumne aqueduct by a 16-mile pipeline tapping into the existing Folsom South Canal. EBMUD's proposed new water supply program specifies instream flows, reservoir operations, and hatchery operations and spawning habitat enhancements to improve fisheries in the Mokelumne River. The water supply benefit of this program is about 43,000 af in drought years. In October 1993, EBMUD's Board of Directors certified the WSMP final EIR and voted to focus planning efforts on the use of ground water storage in San Joaquin County. The Board directed EBMUD staff to continue working with San Joaquin County water interests regarding development of a joint conjunctive use project, with the option of using the District's contract with USBR for 150,000 af per year of American River water.

The District's need for water could change, depending on the outcome of various actions by federal agencies and the SWRCB Mokelumne River water rights hearing. Should any of these actions result in a significant increase in the District's water needs, the District would reexamine all the alternatives contained in the WSMP EIR for meeting the demand.

Monterey Peninsula Water Supply Project. To improve the reliability of water supplies in the Monterey Bay area, the Monterey Peninsula Water Management District has taken a number of actions including water conservation and water reclamation, and has investigated several other water development alternatives. Improvements to the system also are needed to provide water for municipal and industrial users as well as for environmental water needs of the area. Current supply is inadequate during drought years when shortages develop due to lack of adequate carryover storage facilities. The district has investigated 32 alternatives. The current preferred alternative is enlarging a dam and reservoir on the Carmel River. Enlarging Los Padres Reservoir to approximately 24,000 af could provide an average annual water supply of 22,000 af and a drought year supply of about 18,000 af to the Monterey Peninsula's water supply system.

The Metropolitan Water District of Southern California Water Management Programs. MWDSC supplies about 60 percent of the water delivered by its member agencies. These agencies, which cover all or part of six of California's most highly populated counties, serve over 15 million residents. MWDSC's major sources of supply are the SWP and the Colorado River. Ninety percent of the demand on MWDSC's supplies is from municipal and industrial users; the remaining demand is from agricultural users.

Population in MWDSC's service area is expected to increase from 14.8 million in 1990 to more than 22.7 million by 2020. In 1988, MWDSC began a preliminary effort to expand reservoir storage capacity to meet the projected water demands in its service area. Reservoir storage requirements were evaluated in a two-step process designed to establish the combined ground and surface storage needs and to determine the minimum surface storage needed. Three alternative sites for surface storage were selected, including the preferred alternative Domenigoni Valley in western Riverside County, based on the minimum reservoir storage need and a comparison of several sites.



An artist's photocomposite of proposed Domenigoni Valley Reservoir. The reservoir would make MWDSC's supplies more reliable by providing drought-year and emergency storage.

The Domenigoni Valley Reservoir involves constructing two main embankments as well as a large roller-compacted concrete saddle dam as shown on Figure 11-10. The site is near the junction of the Colorado River Aqueduct, the San Diego Pipeline, and the terminus of the East Branch of the California Aqueduct. The reservoir, which could receive water from both the Colorado River and California aqueducts, will have a capacity of 800,000 af.

The reservoir would provide emergency storage, drought year storage, carryover storage, and seasonal storage and enhance operational reliability of MWDSC's system. It would also assist with ground water basin recharge as part of a regional conjunctive use program. Approximately 50 percent of the reservoir capacity would be allocated to emergency storage. The remainder would be used for seasonal regulation and to augment MWDSC supplies by 264,000 af per year during drought years. In October 1991, MWDSC certified the final Environmental Impact Report for the Domenigoni Valley Reservoir Project. The current MWDSC schedule indicates that the project would be operational by the end of this decade. However, it could take five or more years to fill the reservoir, so the full benefit of the reservoir may not be realized until after the year 2004.

Arvin-Edison—MWDSC Conjunctive Use Program is another supply augmentation program that MWDSC is investigating. The Arvin-Edison Water Storage District and MWDSC agreed on a complex conjunctive use program which allows Arvin-Edison to provide CVP entitlement water to MWDSC in dry years and use ground water pumped from previously stored ground water supplies made available by MWDSC from SWP supply in wet years. As originally envisioned, the project would have provided 93,000 af of drought year supply. However, recent actions to protect aquatic

MWDSC Reliability Planning Process

MWDSC concentrates on the development and management of sufficient and high-quality water to meet the needs of its service area in an innovative and cost-effective manner that will sustain the economy and quality of life in Southern California. MWDSC's water supply reliability objective is as follows:

Even under the most severe hydrologic event, MWDSC will never provide less than 80 percent of full service to its customers; full service meaning wholesale demand for imported water, after accounting for the implementation of water management programs and conservation best management practices, within its service area.

This water supply reliability objective was developed after balancing the costs of resource expansion, economic impacts of water shortages, and practical levels of implementing water conservation and other management programs. In order to assess and review the water reliability objective, MWDSC follows an on-going systematic procedure to ensure that the objective is effective. This procedure is summarized below:

1. Project Water Demands
2. Determine Quantities and Probabilities of Water Supply
3. Identify Potential Water Management Strategies to Meet Demand
4. Compare Total Available Water Supplies to Water Demands
5. Determine Frequency of Water Supply Shortages
6. Determine Costs and Benefits of Increasing Supply Reliability

Water Demand Projections. MWDSC forecasts water demands using a sophisticated computer model known as MWDSC-MAIN, a regional version of the national IWRMAIN water demand model, calibrated for the South Coast Region. MWDSC-MAIN projects water demands based on demographic and economic trends such as population, housing, family size, personal income, commercial and industrial employment, labor rates, climate, and the price of water service. The model also takes into account long-term water conservation, such as that anticipated from the implementation of the "best management practices." These projected water demands can vary substantially from one year to the next. The variation in water demands is attributed mainly to weather and economic cycles such as recessions. Therefore, MWDSC presents its demand projections ranging from low to high.

Quantities and Probability of Water Supplies. Water supplies will vary due to hydrology, weather, and operation of the supply system. Since it is impossible to accurately predict weather, historic years of hydrologic record are used to estimate the future probability of supply. MWDSC uses the DWRSIM operations model to determine the probability of SWP supplies using 70 years of historic hydrology. The other major supplies available to Southern California are: (1) Colorado River water; (2) local ground and surface water; and (3) the Los Angeles aqueducts. The probabilities of receiving these water supplies were also estimated based on similar hydrologic analyses.

Estimating Potential Water Management Strategies. MWDSC explores all feasible demand management and water supply options in meeting the growing water needs of its service area. These options not only include traditional supply sources mentioned previously and voluntary water transfers, but also water management programs such as waste water reclamation, ground water recovery programs, conjunctive use and storage, and conservation. MWDSC's approach in determining how to meet future demands is to evaluate all of its available water supply and management programs based on reliability, costs, flexibility, and other considerations. Projections of supply resulting from water management programs are estimated based on existing and potential local and regional projects.

Comparisons of Water Supply to Demand. After the projections of water supplies are determined, they are compared to the projections of water demands. Figure M-1 presents the minimum supplies available during the record drought and a projection of future supplies.

MWDSC Reliability Planning Process (continued)

The water demand forecast reflects: (1) the latest demographic projections; (2) the recent effect of the statewide drought; and (3) the effects of the current economic recession. The existing supplies, which are identified, do not meet full service demands. Even with aggressive water conservation and waste water reclamation (which together represent about one-half of all new supplies and demand reduction efforts), there is a substantial shortage throughout the planning period. Additional aqueduct supplies, surface and ground water storage programs, and water transfers are needed to meet the full service needs of the region.

Comparing all possible water demand and supply projections yields the frequency of supply shortages for Metropolitan. Figure M-2 presents the water supply reliability for MWDSC's wholesale deliveries. The vertical axis represents the percentage of MWDSC shortage in the year 2010. The horizontal axis represents the frequency of the shortage occurring. The reliability is presented in four scenarios.

The first scenario represents "no new investment" for either water management programs or water supply expansion. Under the "no new investment" scenario, MWDSC would experience a wholesale supply shortage of at least 60 percent (on average) every other year. At the retail level, regional water shortages for this same scenario would be about 30 percent every other year (since MWDSC supplies about half of the total water supplies to the region).

The second scenario adds the conservation BMPs, which improve the supply reliability. Potential waste water reclamation is added in the third scenario, which further improves the supply reliability. Under the third scenario, the wholesale supply shortages would be at least 27 percent every other year.

In order to achieve the fourth scenario, substantial investment is needed to improve aqueduct supplies, build an 800,000-af storage reservoir, implement ground water programs, build and improve pipelines and treatment facilities, and purchase water through voluntary transfer agreements. This scenario is the reliability goal determined by MWDSC to be justified by a cost and benefit analysis.

Estimating Costs and Benefits of Reliability. Estimating the costs and benefits of increasing supply reliability is difficult because it is impossible to account for and quantify many of the true economic costs caused by supply shortages. While some economic impacts of rationing can be estimated, other economic and social consequences of severe water shortages are intangible. In addition, rationing becomes less effective and more costly over time because of the implementation of long-term institutionalized conservation practices, such as the BMPs. Accounting for this phenomenon of *demand hardening* is critical to the determination of shortage costs.

In order to determine a lower bound estimate of the benefits of increased supply reliability, MWDSC attempted to quantify as many of the economic impacts due to rationing as possible. To estimate the effect that rationing has on the residential sector, a contingent valuation survey was used to determine how much households would pay to avoid severe water shortages. The survey, conducted in 1987, found that customers would pay (on average) an additional $10 to $20 per month every other year to avoid shortages greater than what was experienced in 1991. This willingness to pay for reliability improvement for all residential customers in MWDSC's service area totals over $1.5 billion per year.

To estimate how shortages impact the industrial sector, MWDSC used the results of the *Cost of Industrial Shortages* (prepared for the California Urban Water Agencies in 1991). This study indicated that the impact of allocating a 15-percent shortage to Southern California's industrial sector would be a loss of about 16,000 jobs and over $3 billion in production.

Figure M – 1. MWDSC Water Supply and Demand: Critical Drought Year

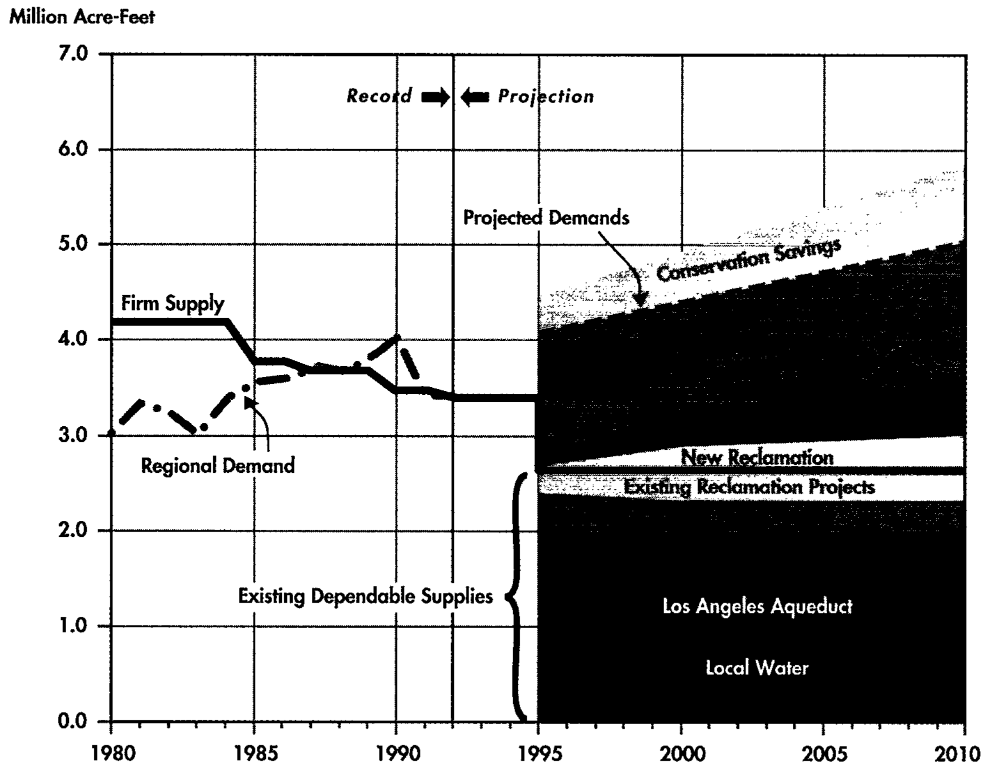
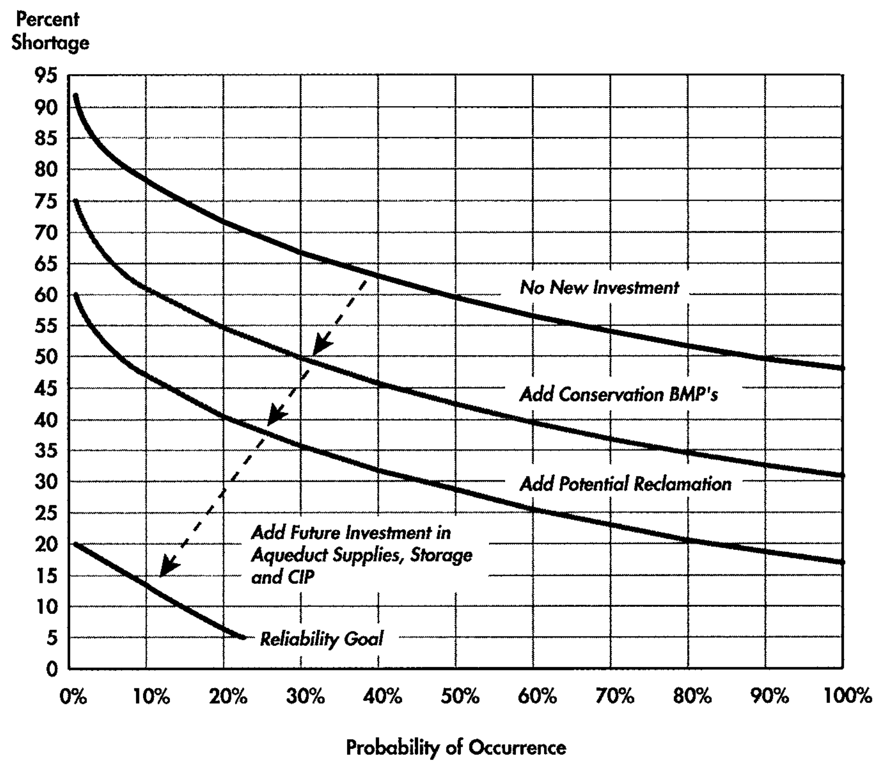


Figure M – 2. MWDSC Supply Reliability in Year 2010



NOTE: Projections for existing supplies are conservative since they do not account for the probability of having surplus water.

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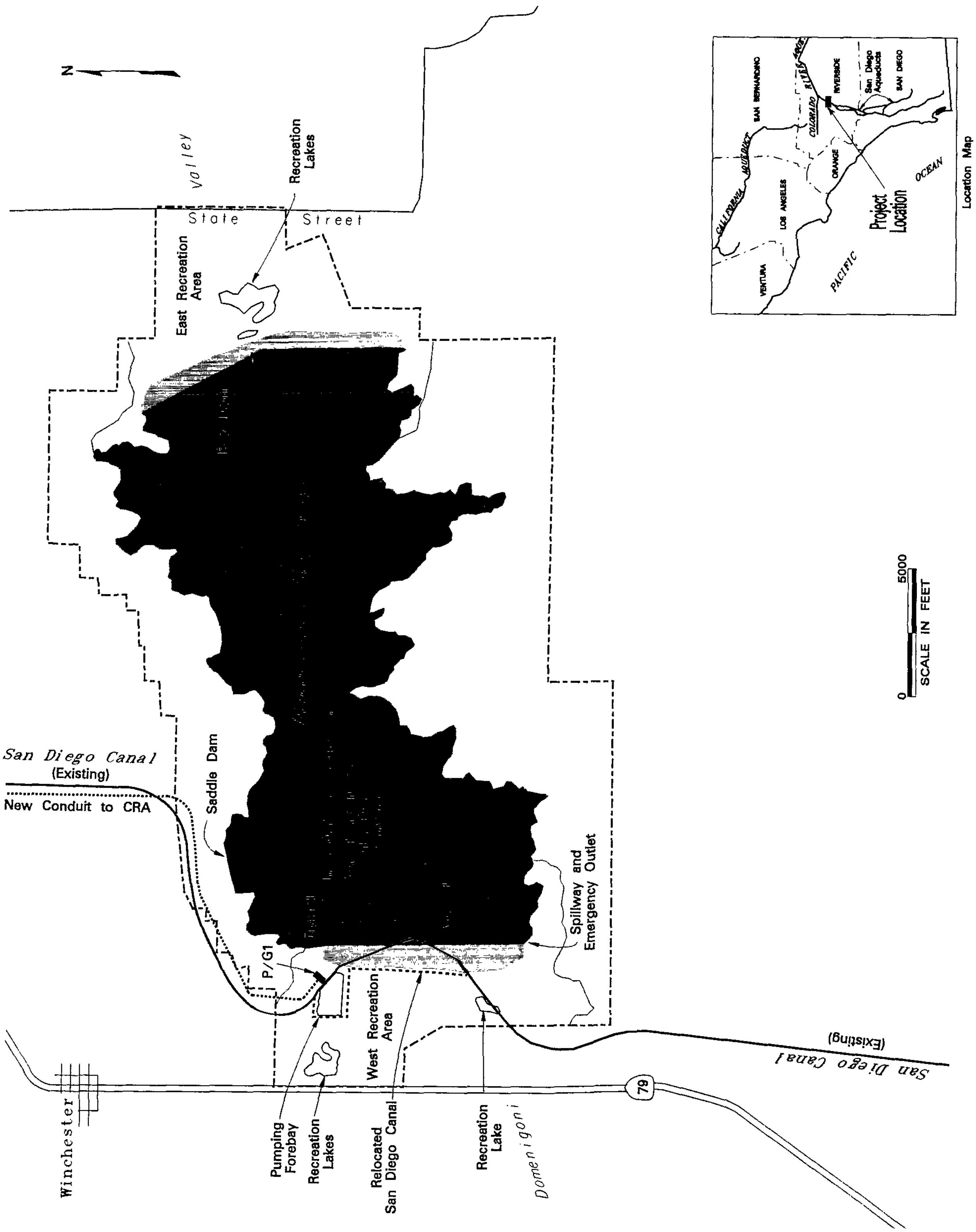
Figure 11-10. Domenigoni Valley Reservoir Site and Facilities



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species in the Delta and implementation of the CVPIA have restricted operations in the Delta. Consequently, MWDSC and Arvin-Edison are currently reassessing the project.

MWDSC's Inland Feeder is a 45-mile-long conveyance facility which will bring supplemental SWP water supplies to Riverside, San Bernardino, San Diego, Orange, and Los Angeles counties. The facility would be intended to help MWDSC preserve operational reliability, optimize use of existing water resources, and meet increasingly stringent State and federal water quality standards through blending of supplies.

Pajaro Valley Water Authority Water Augmentation Program (San Felipe Extension). The Pajaro Valley Water Management Authority is analyzing whether or not to take water from the CVP's San Felipe Division. The proposed San Felipe extension would consist of a 22-mile pipeline from the Santa Clara Conduit to the Watsonville area which could supply a maximum of 19,900 af annually of CVP water for municipal and industrial, as well as agricultural, use in the Watsonville area. The San Felipe extension is a water conveyance rather than a water supply augmentation project. The supply for the project will come from reallocation of CVP supply pumped from the Delta.

City of San Luis Obispo—Salinas Reservoir. The City of San Luis Obispo has actively been pursuing the Salinas Reservoir Expansion Project to supplement its water supply. The project involves installation of spillway gates to increase the storage capacity of the existing reservoir by about 17,950 af—from about 23,840 af to 41,790 af—and the city's supplies would increase by about 1,650 af. The Environmental Impact Report for the project is expected to be certified in 1994.

Level II—Reliability Enhancement Options

Following is a brief discussion of demand management and supply augmentation concepts or projects which are not specifically quantified but, through some combination of actions, could fill the gap between supply and demand shown in the California water budget, Chapter 12. Plans for some of these projects are on hold for various reasons, including the need for a long-term solution to Delta problems, but work could be resumed at any time to help meet California's growing water needs. Some others, programs such as San Diego County Water Storage Project and Conjunctive Use Programs, are very active but are in the early stages of planning and further studies are needed to determine the water supply benefits of such programs. Table 11-8 summarizes Level II water management options.

Long-Term Demand Management Options

Increased Agricultural Water Use Efficiency. A 73-percent seasonal application efficiency is defined as a statewide target in Chapter 7 and has been supported by many irrigation experts in a variety of reports. This coincides with the draft report *On-Farm Practices* prepared for the Agricultural Task Force of the State Water Conservation Coalition. The 73-percent target efficiency relies on: (1) subtracting any effective precipitation from the evapotranspiration requirement of the crop; (2) attaining an 80-percent distribution uniformity; and (3) adding a very small leaching requirement. This target assumes that all portions of farm fields will be fully irrigated. The target efficiency considered an appropriate Level I option is shown by the formula below.

$$\mathrm{SAE} = \frac{\mathrm{ETAW} + \mathrm{LR}}{\mathrm{AW}} = 73\%$$

where: SAE is the seasonal application efficiency; ETAW is the evapotranspiration minus effective precipitation; LR is leaching requirement; and AW is the applied water.

Table 11-8. Level II Water Management Options

Program	*Type*	*Supply Augmentation or Demand Reduction (1,000 AF)*	*Comments, Concerns, Problems*
Demand Management:			
Agricultural Water Conservation	Demand Reduction	300 [a]	Increased agricultural water use efficiency
Urban Water Conservation	Demand Reduction	220 [a]	Increased urban water use efficiency
Land Retirement	Demand Reduction	477 [a]	Retirement of land with poor drainage disposal in west side San Joaquin Valley
Water Transfer	—	800 [b]	Institutional constraints
Statewide Supply Management:			
Stanislaus-Calaveras River Water Use Program	Conjunctive Use	80 [c]	DWR, USBR, and local agencies are conducting studies.
Sacramento Valley Conjunctive Use Program	Conjunctive Use	100 [c]	Initial studies under way by DWR and local agencies.
Red Bank Project	Storage	40 [c]	
Shasta Lake Enlargement	Storage	1,450 [c]	
Clair Engle Lake Enlargement	Storage	700 [c]	
Westside Sacramento Valley Project	Conveyance	—	
Westside Reservoirs	Storage	up to 2,000 [c]	
Mid-Valley Canal	Conveyance	—	
Folsom South Canal Extension	Conveyance	—	
American River Water Resources Investigation	Storage	—	
Local Water Management:			
Use of Gray Water	Reclamation	180 [c]	Requires investment in separate plumbing; health concerns.
Water Recycling	Reclamation	370 [c]	Estimated ultimate potential
Water Desalting	Reclamation	390 [c]	
Reuse of Agricultural Brackish Water	Reclamation	—	High salt accumulation in soil
San Diego County Water Authority Water Resources Plan	Variety of Programs	85 [c]	Plan includes water recycling, ground water development, and desalination of brackish water.
Santa Clara Valley Water Management	—	—	Studies by district in progress; will need 100,000-150,000 AF additional supplies by 2020.
Delta Storage	Storage	—	Water quality, THM concerns
Watershed Management	—	100 [c]	Increases runoff from the watershed, environmental concerns.

(a) Reduction in applied water.
(b) Reallocation of supply for short- or long-term transfers.
(c) Average annual supply.

Level II agricultural demand reduction is based on a statewide agricultural irrigation efficiency of 75 percent. The feasibility of increasing agricultural irrigation efficiency over 73 percent should be further investigated because of potential reduction in yield due to under-irrigation, which may occur in part of each field. For example, Westlands Water District has estimated that irrigation efficiencies could reach 75 percent in their service area at an 80-percent distribution uniformity. However, approximately 12.5 percent of each field is under-irrigated using this formula according to Westlands Water District's Water Conservation Plan (July 1992). If under-irrigation of this magnitude is considered acceptable, an additional statewide annual reduction in applied water of approximately 300,000 af could be attained and considered as a Level II option. Reduction in depletion would occur only in areas from which outflow enters a saline sink such as the west side of the San Joaquin Valley and Imperial Valley. However, because irrigation efficiency in Imperial Valley and Westlands Water District has already reached 75 percent, this option will not reduce depletions. The positive or negative effects of reducing applied water would have to be evaluated on a case by case basis.

Increased Urban Water Use Efficiency. The Level I urban water conservation estimates were based on Best Management Practices, which included three landscape-related BMPs that were quantified and ultra-low flush toilet replacement, among others. Two of the three landscape BMPs relied on the Model Water Efficient Landscape Ordinance developed by DWR. The criteria developed under this ordinance resulted in the following formula used to estimate the maximum applied water allowance in a landscape plan:

$$\text{MAWA} = \frac{0.8(\text{Eto}) \times \text{LA}}{\text{CF}}$$

where: MAWA is the maximum applied water allowance; 0.8 is an ET adjustment factor based on an irrigation efficiency of 62.5 percent; Eto is the reference evapotranspiration of well watered pasture; LA is the landscaped area; and CF is a conversion factor to hundreds of cubic feet.

For a Level II option, an increase in irrigation efficiency of 5 percent should be investigated. The rationale behind this assumption is that this would parallel the increase in agricultural efficiency over the same period. If landscape irrigation efficiency is increased by 5 percent, an additional 220,000 af in applied water reduction would be realized. This amount would be commensurate with a 190,000-af reduction in net water use. Other potential Level II options that need further evaluation include: greater increases in landscape irrigation efficiencies; evapotranpiration reduction from xeriscaping; and horizontal axis washing machines.

Applied Water Reduction Due to Land Retirement. *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley* (San Joaquin Valley Drainage Program, 1990) reported that many of the valley's water and drainage districts and individual growers had begun to take actions similar to those recommended in the report. Therefore, it was assumed in Chapter 6, *Agricultural Water Use*, that the source control (irrigation efficiency improvements) and land retirement elements of the recommended plan developed by the SJVDP would be implemented by 2020. Implementation of these two elements would result in an applied water reduction of 232,000 af by 2020. This was adopted in the Level I scenario and included in water demand projections.

The SJVDP report also suggested that if no portion of the recommended plan were implemented, applied water could be reduced by 1,040,000 af due to the abandonment of 460,000 acres of irrigated land by 2040. Assuming that the abandoned acreage increases linearly over time results in an estimate of 276,000 acres abandoned by 2020 and a reduction in applied water of 689,000 af if no portion of the plan were implemented. The analysis also assumed that approximately 20,000 af of source control would occur.

Therefore, to establish a Level II option scenario, it is assumed that the SJVDP recommended plan will be partially implemented by 2020, reflecting the status of various recommendations in the report, resulting in a potential applied water reduction of about 477,000 af from land abandonment and source control. This amount would correspond to a reduction in net water use of 390,000 af. Table 11-9 illustrates what could be available due to partial implementation of that preferred plan. However, more detailed analysis is required to determine whether the water would be used for other agricultural production in the region.

Water Transfers. Water transfers can augment an area's water supplies on a short- or long-term basis. Short-term transfers are generally either one-time spot market or long-term agreements for drought year supplies. Long-term annual transfers are generally designed to augment a water agency's year-to-year supplies over the long-term to improve the water service reliability for the receiving area. Such transfers have been going on since early this century as evidenced by the construction of several major intrastate transfer facilities (described in Chapter 3), and they are indeed the backbone of the State's long-existing water delivery system. However, the 1987-92 drought caused some water agencies and individuals to begin looking at the potential of a water transfers market to meet their needs by augmenting long-term supplies as well as short-term drought supplies.

There are currently physical limits to water transfers. Total usable transfer capacity of existing major conveyance facilities from the Delta, under D-1485, during drought years is about 1.4 maf per year. Level I drought water transfers from the Delta are estimated at 0.6 maf, resulting in a remaining Level II transfer potential of about 0.8 maf. (See *Short-Term Water Transfers* in the *Level I—Reliability Enhancement Options* section of this chapter.) The unused capacity of conveyance facilities is considerably less during average years when both projects would be able to export more of their own water. However, recent actions taken to protect fisheries in the Delta have considerably curtailed the pumping capability of the projects, resulting in increased limitations on the SWP and CVP facilities to convey or wheel transfer water. Drought year usable transfer capacity of the SWP and CVP at the 1990 level is estimated to be about 0.7 maf when projects are operated to comply with Delta smelt and winter-run chinook salmon 1993 biological opinion, as discussed in detail below. The primary sources of water for transfer have been ground water substitution, unallocated developed supply, and land fallowing. This section presents the factors affecting

Table 11-9. Applied Water Reductions by 2020 With and Without Implementation of the Plan Recommended by the San Joaquin Valley Agricultural Drainage Program[1]

	Without Recommended Plan	*With Recommended Plan*[2]
Water made available by land abandonment[3]	689,000	0
Water made available through land retirement[4]	0	119,000
Water conserved through source control[5]	20,000	113,000
Subtotal	709,000	232,000
Difference (Without-With)	477,000	

(1) Source: straight-line interpolation from data in "A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley, Final Report of the San Joaquin Valley Drainage Program," September 1990.

(2) Recommended plan elements adopted in DWR Bulletin 160-93 projections.

(3) Land abandonment due to 276,000 acres forced out of production due to no drainage plan implementation by 2020.

(4) Land retirement refers to the planned retirement of 45,000 selenium-laden acres.

(5) Source control is equivalent to applied water reductions to reduce drainage volumes.

the feasibility of transferring water along with a general discussion of sources of water for transfer.

Ground water substitution makes surface irrigation water available for transfer by pumping an equivalent amount of ground water for use on irrigated lands. Local water districts usually coordinate ground water pumping with reduced surface water diversions by growers, although growers not affiliated with a local water district have also participated in ground water substitution contracts. Replacement pumping must be far enough from perennial streams, rivers, and Delta tributaries to not induce additional immediate percolation to ground water, thus reducing surface water supplies and negating the transfer.

Unallocated developed supply, which would have stayed in storage and possibly spilled in future years, can be available for transfer if the transferee obtains approval from the SWRCB and makes assurances that reregulation of reservoir operations will not adversely affect operations of the SWP or CVP. This is essential, because SWP and CVP facilities are used to transport most transferred water and must meet downstream water quality standards obligations in the Sacramento-San Joaquin Delta.

Temporary fallowing of irrigated crop land is the water transfer alternative with the most potential for providing short-term water supply during drought, thus improving water service reliability for areas receiving the water. By not planting a crop, or by withholding irrigation from a crop already planted, or by shifting from a high-water-using crop to a lower-water-using crop, growers are able to free up irrigation supplies for transfer. Since drainage water is normally used on other farms, or maintains wildlife habitat, the amount of water transferred is usually limited to the average consumptive use (evapotranspiration of applied water for specific crops) on the transferring farm, plus drainage if it goes to a saline sink.

Permanent fallowing or land retirement is a long-term transfer strategy similar to temporary fallowing. The most attractive agricultural land for this type of transfer is land with salinity problems, or of only marginal production. The 1992 Castaic Lake Water Agency transfer of Devil's Den Water District SWP supplies is a good example of permanent land retirement although the actual retirement of the land is still several years away.

Physical limitations to water transfers exist within the conveyance capability of the various water systems. The San Francisco Bay, the South Coast, the west side of the San Joaquin Valley, and the Tulare Lake regions are regions with water shortages, and these regions would likely be primary purchasers of water transfers. A key factor in water transfers to these regions is the Delta because the potential sellers of surplus water for interregional water transfers would primarily be in areas of surplus, such as the Sacramento River Region, and to a lesser degree, the San Joaquin River Region.

The following water transfer discussions involving the hub of California's water supply infrastructure, the Delta, are based on SWRCB D-1485 and project operations under winter-run salmon and Delta smelt criteria. Actions taken in 1992 and 1993 to protect fisheries in the Delta have already considerably reduced export capabilities.

Most major water transfer actions require participation of SWP or CVP as facilitator to convey the transferred water to the areas of need, and approval from the SWRCB to change the point of diversion and place of use. Availability of unused capacity of pumping plants and conveyance facilities is critical in determining the feasibility of wheeling water to the receiving agency, particularly for long-term fixed annual deliveries.

The CVP's Tracy Pumping Plant is generally used to almost full capacity to meet existing contractual commitments. However, during times of drought, there is unused CVP capacity which is considered in this analysis. The SWP's California Aqueduct capability is constrained at several critical locations which restrict excess capacity to convey transfer water. These constraints are Banks Pumping Plant, Reach 13 of the California Aqueduct upstream of Buena Vista Pumping Plant in the lower San Joaquin Valley, and Edmonston Pumping Plant, where water is pumped over the Tehachapi Mountains into the upper desert and South Coast Region.

Under D-1485, and the USCE permit (public notice 5820A, amended) with existing facilities, Banks Pumping Plant restricted capacity is about 6,400 cfs with limited additional capacity in winter and spring. The Banks Pumping Plant is physically capable of pumping approximately 10,300 cfs. With implementation of the proposed south Delta water management program and USCE pumping restrictions removed, Banks Pumping Plant capacity could increase to approximately 10,300 cfs under certain conditions. Edmonston Pumping Plant would then become the critical constraint in conveying water to the South Coast Region. Under endangered species operation criteria, constraints at Tracy and Banks pumping plants significantly reduce water transfer capabilities.

Two operation studies were evaluated to determine the unused capacity of SWP and CVP facilities for the 1990 level of development, with D-1485 and with endangered species criteria based on the 1993 Delta smelt and winter-run chinook salmon biological opinions. The "take limitations" criteria imposed by the opinions cannot be modeled and are not included in the analyses. Another set of studies was conducted to evaluate year 2020 usable transfer capacity of the conveyance systems with existing facilities and with Level I water management programs based on D-1485 criteria.

Table 11-10 shows annual SWP and CVP usable transfer capacity from Banks Pumping Plant to the South Coast and San Francisco Bay regions, based on D-1485 operating criteria. Unused CVP capacity at Tracy Pumping Plant and Delta Mendota Canal are also included in the analyses. Unused capacity of the projects is directly related to annual hydrologic variations and the demand for water in the SWP/CVP service areas. During drought periods when supplies are insufficient to meet demands and deficiencies are imposed on SWP and CVP water contractors, more unused capacity is available in the conveyance systems. In addition, as demands for water in SWP

Table 11-10. SWP and CVP Usable Transfer Capability from the Delta
(millions of acre-feet)

To the South Coast Region (based on D-1485)

	average	*drought*
1990, Base Case	0.6	1.4
2020, with Existing Facilities	0.3	1.5
2020, with Level I Programs	0.3	1.1

To the San Francisco Bay Region (based on D-1485)

	average	*drought*
1990, Base Case	0.2	0.3
2020, with Existing Facilities	0.1	0.3
2020, with Level I Programs	0.1	0.2

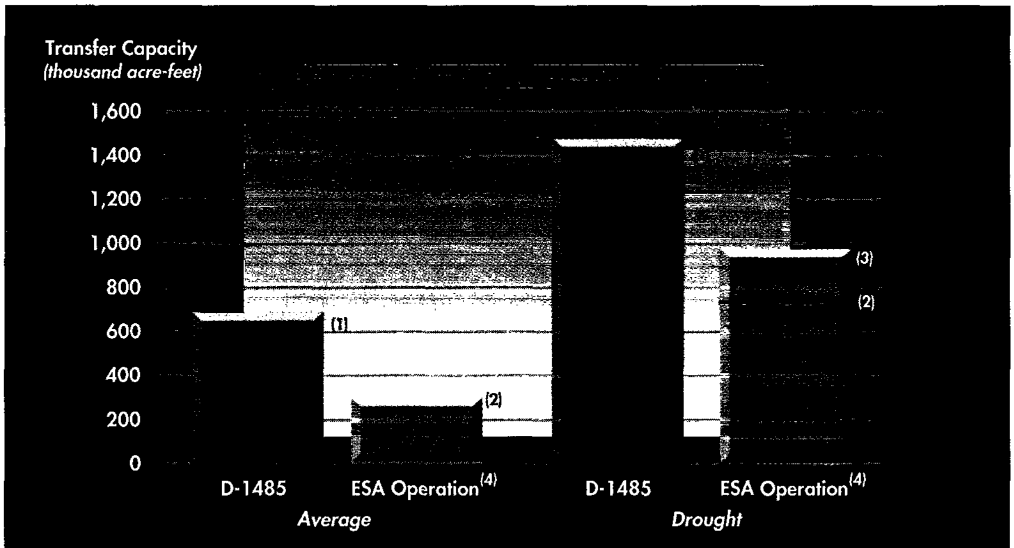
service areas increase and additional facilities are completed to meet contractual demands, unused capacity of the SWP decreases.

For the South Coast Region, the 1990 level of usable transfer capacities in drought and average years under D-1485 criteria are about 1.4 and 0.6 maf, respectively. By year 2020, with Level I water management programs, unused capacity of the projects will be reduced to 1.1 and 0.3 maf in drought and average years, respectively. Similar analyses conducted for the San Francisco Bay Region indicate that the combined usable transfer capacity of the SWP North and South Bay Aqueducts and the CVP San Felipe unit (Santa Clara Conduit) for the 1990 level varies from 0.3 to 0.2 maf for drought and average years respectively. By year 2020, with Level I water management programs, usable transfer capacity will be reduced slightly to 0.2 and 0.1 maf for drought and average years respectively.

Transfer capability from the South Delta shown for the San Francisco and South Coast regions was computed independently and is not additive. The Delta Pumping Plant's unused capacity is not adequate to convey enough water to fill the combined unused capacity of the aqueduct systems conveying water to the two regions. SWP and CVP usable transfer capability from the Delta to the San Francisco Bay Region is shown in Table 11-10.

Figure 11-11 compares the SWP and CVP water transfer capacity from the Delta to the South Coast Region under D-1485 and endangered species criteria. This figure shows that average and drought year usable transfer capacities of the SWP and CVP are reduced to about 0.3 and 0.7 maf, respectively, for the 1990 level when projects are operated under endangered species criteria for winter run salmon and Delta smelt, reflecting pumping curtailments resulting from endangered species biological opinions. Among the factors limiting Delta exports are reverse-flow criteria and take limitations.

Figure 11-11. Usable Transfer Capacity with Existing SWP/CVP Facilities for Transfers from the Delta to the South Coast Region (thousands of acre-feet)



(1) Usable transfer capacity from the Delta under D-1485 conditions.

(2) Usable transfer capacity from the Delta under historic Delta flow patterns with ESA restrictions.

(3) Usable transfer capacity including capability to transfer south of the Delta source supplies that do not add to reverse flow problems thus allowing more water to be pumped than under historic Delta flow patterns.

(4) Based on 1993 Delta Smelt Biological Opinion and Winter Run Salmon Biological Opinion. However, figures do not reflect pumping curtailments due to 'take' limitations.

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Usable transfer capabilities discussed here do not reflect pumping limitations due to take limits under the biological opinions.

Water transfers with source water from south of the Delta, for example the San Joaquin Region, would not have reverse-flow limitations, but would be subject to other pumping restrictions. If source water for transfer is from the San Joaquin River, an additional pumping of about 0.2 maf in drought years could be realized as shown in Figure 11-11. Therefore, the water transfer capabilities mentioned for through-Delta transfers are less than those for source water from south of the Delta. Thus, considering pumping limitations in the Delta and Edmonston Pumping Plant, an envelope of usable transfer capacity can be developed. The envelope for water transfers to the Southern California ranges from an upper limit of 1.4 maf (under SWRCB D-1485) to about 0.9 maf in drought years (under endangered species actions). Similarly, the average year Delta water transfer envelope for exports to Southern California would be about 0.3 to 0.6 maf under endangered species actions and SWRCB D-1485, respectively. None of these restrictions consider potential pumping curtailments at the Delta due to take limits imposed by biological opinions.

Other considerations that could impair water transfers include lack of willing buyers and sellers, potential third-party impacts, and timing of availability of unused capacity of the facilities. Figure 11-12 shows the monthly variation of unused capacity of the SWP and CVP, under D-1485 for the 1990 level, and indicates that unused capacity of conveyance facilities is extremely limited from May through July when demand for water is high and SWP and CVP pumping is limited by D-1485 criteria. Therefore, most long-term water transfers are limited to those agencies that have re-regulation and storage capabilities that can be operated to take advantage of timing of available transfer capability. However, short-term drought year transfers, such as Drought Water Bank transfers, can use unused SWP/CVP storage (nonproject contractors may have a lower priority for storage) and re-regulation capabilities to facilitate transfer of water to agencies without storage capacity.

Water Rights Law is paramount in any discussion about water transfer. Virtually all of California's developed surface water is committed under riparian or appropriative water rights. Water rights laws and institutional constraints constrain the ability to

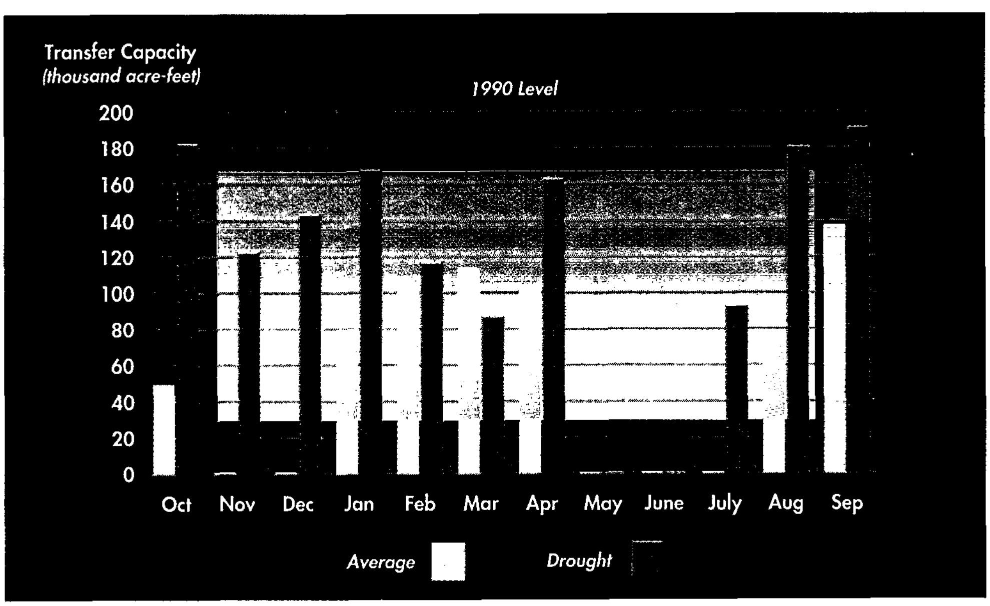

Figure 11-12. Monthly Variation of Usable Transfer Capacity with Existing SWP/CVP Facilities for Transfers from the Delta to the South Coast Region Based on D-1485 (thousands of acre-feet)

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make water transfers. Statutes governing California water rights are generally administered by the SWRCB . Water transfers lasting more than a year generally require the water right holder to petition the SWRCB for approval. There are different procedures for temporary (one-year) and permanent (long-term) transfers.

The *Central Valley Project Improvement Act* permits water districts and individuals receiving CVP water to transfer that supply to any other individual or entity subject to conditions specified in the Act, and subject to a federal approval process. The transfer must be approved by the affected district if the amount of the proposed transfer would exceed 20 percent of a district's CVP contract amount.

Transfers carried out in accordance with the Act must meet the conditions specified therein, and must comply with relevant State and federal laws such as CEQA, NEPA, and the State and federal Endangered Species Acts. Transfers must also comply

Water Transfer Costs

Water transfer costs include more than the amount that prospective sellers would be willing to accept for their water. Other associated costs can be a substantial or even the major part of the cost of a water transfer. Mitigation for adverse third-party economic impacts in the area of origin may require payments to local agencies; as a consequence, freeing up water for transfer has at least two cost components.

Purchase prices can be set by a drought water bank-type operation or directly negotiated between prospective buyers and sellers. Negotiated prices will fall between the cost to the sellers of foregoing the use of that water and the willingness of the buyers to pay.

The cost to the sellers is affected by the magnitude of the transfer. If available, initial quantities probably involve in-lieu ground water pumping or releases of uncommitted stored water. These sources are likely to be least costly to the sellers in terms of pumping energy or foregone income. Further increments of water likely will involve crop fallowing or switching to lower-water-using crops. These actions result in substantial income losses to sellers and, as a consequence, are likely to require higher water prices to make them palatable.

Higher prices are more likely in a spot market than under a long-term agreement. Spot markets favor the seller; there is little doubt about the buyer's immediate need for the water. Buyers have a certain advantage under long-term agreements. Under long-term agreements the seller is trying to reduce or eliminate the uncertainty of income from water sales and the buyer is not necessarily facing an immediate crisis, but is planning to augment supply reliability. Prices paid by buyers of transferred water reflect the cost of conveyance, which depends upon the facilities used.

The conveyance losses reduce the water delivered compared to the amount purchased. Alternatively, these losses may be thought of as increasing the unit cost of the remaining water to the buyer, that is, as water surcharges. If the transferred water has to be moved across the Delta under controlled flow conditions, a portion of the water must be dedicated to Delta outflow as a means of meeting Delta salinity standards. This is an example of a conveyance loss. Other conveyance losses include evaporation from reservoirs and canals as well as canal seepage.

Water surcharges for environmental mitigation needs, such as increasing stream flows for anadromous fish spawning, can also be a requirement for permitting transfers.

Short-term emergencies generally are characterized by the prospect of large economic losses from unmet demands and the high cost or limited nature of the options to meet those demands or to mitigate the losses. Under these conditions even a relatively small quantity of transferred water can eliminate the most serious impacts of shortage. The willingness of buyers to pay is correspondingly high.

with USBR's interim Guidelines for Water Transfers and must eventually comply with long-term water transfer rules and regulations when they are promulgated. The restrictions contained in the guidelines apply in particular to transfers of project water, rather than to transfers of water rights settlement water conveyed by the CVP. Given the restrictions placed on transfers of project water, it is likely that transfers of water rights settlement water may constitute much of the total CVP-related supply being made available for transfer. The CVP Improvement Act also contains provisions allowing use of project facilities to carry out water banking programs, including banking programs for fish and wildlife.

Delta Outflow Requirements are another factor affecting water transfers. Minimum water quality standards for the Delta are set by the SWRCB and the SWP and CVP must be operated to meet those standards. Presently, Delta outflow is maintained by either limiting exports or increasing releases from upstream reservoirs. Since most transfers of water originating in the Sacramento Region must be conveyed through either the SWP or CVP Delta facilities, transfers must conform to existing and future Delta outflow requirements.

Threatened and Endangered Species must also be considered when discussing water transfers. Potential impacts of transfers on listed species must be evaluated under the State and federal Endangered Species Acts. CVP/SWP pumping from the Delta is currently restricted to protect listed species. The lack of Delta transfer capacity rather than the general availability of supply may be a common occurrence.

Environmental Impacts of a water transfer are another factor to consider. The quantity and timing of reservoir releases are very important and can have significant impact upon instream fish flows. Careful consideration and coordination with DFG is required. For example, the Drought Water Bank water was transferred later in the year to minimize impacts upon chinook salmon and Delta smelt. However, conjunctive use programs can have a positive effect on aquatic resources by using ground water for irrigation during dry years, thereby reducing direct pumping from the river which results in fewer fish being taken through unscreened intakes.

Not all negative impacts on wildlife can be eliminated. Land fallowing has some negative impact on wildlife habitat, by cutting off some food sources, vegetation for cover, and nesting. Any future fallowing contracts are expected to contain provisions to minimize these impacts. Water transfers also can substantially reduce surface flows to waterfowl areas which are depended on to provide habitat for migrating and resident birds using cultivated crops as food and nesting sources.

Impacts on Transferring Area are important. Two concerns with water transfers involve the impacts on local ground water levels and impacts on local tax revenues and economies. For example, those issues arose during the 1991 Drought Water Bank due to the replacement of transferred surface water with ground water, sale of pumped ground water, and the fallowing of more than 150,000 acres.

Review and evaluation of ground water data indicate little impact on ground water levels from the State Water Bank transfers that took place in 1991 and 1992. Monitoring programs have been established in areas where such ground water pumping took place. Approximately 100 wells, part of DWR's usual semi-annual monitoring program in Butte, Colusa, and southern Glenn counties, were monitored monthly during the transfer and subsequent recovery periods. The monitoring program did not indicate any significant impact on the ground water basins in these counties as the result of ground water pumping for the State Drought Water Bank. Local concerns regarding future water transfers will be assessed through expanded ground water monitoring similar to those implemented as part of the 1991 and 1992 Drought Water Bank programs.

Transfer from agricultural water use to urban use is a concern because many agricultural areas are considered more economically vulnerable than urban areas. Although not all water transfers from land fallowing go to urban areas, urban areas have a relatively higher ability and willingness to pay for water during shortages, which makes them the likely recipients of water transfers to shore up water service reliability.

The economic health of farm communities is tied to the farm activity within their spheres of influence. For many local businesses the goods and services furnished to farmers is a major part of their income. If farm production declines, whether because of drought, government programs, or crop land fallowing for water transfers, a ripple effect happens in the local economy. These supporting businesses will likely see less sales income, and if there is less business income, employees may be terminated or asked to work fewer hours, reducing the amount of salaries paid. In turn, the employees spend less money in the community, and another round of adverse impacts results.

Any resulting unemployment can be an additional burden on local governmental and private agencies that provide services to unemployed and indigent people. Compounding this problem is the likelihood that, due to the aforementioned decline in business activity, these same agencies will be facing revenue cutbacks from falling tax income and fewer charitable contributions. However, payments for the transferred water, water surcharges, and controls on land fallowing can be used to mitigate these impacts. For example, the 1991 State Drought Water Bank experience showed that many farmers used water sales income to make improvements to their land, providing jobs and income within the local area. Restricting the percentage and frequency of land fallowed within any one area can allow affected communities to avoid much of the potential permanent economic or social damage.

Water Supply Management Options

Level II supply management options discussed here are those actions that could augment supplies in water-short areas of California. Table 11-8 also shows statewide and local water supply management programs under Level II options.

SWP Water Supply Augmentation. The following conjunctive use options offer potential means to further enhance the SWP reliability. These are not, by any means, meant to be all-inclusive; other options could also be identified and investigated in the future for augmenting SWP supplies.

Conjunctive use of surface and ground water supplies can be an efficient means of augmenting supplies to help meet California's future water needs. Conjunctive use is the operation of a ground water basin in coordination with a surface water supply system to optimize the combined yield. A surface water storage and conveyance system is used to recharge a ground water basin, either directly or indirectly, during wet years to provide storage of water that can be used during dry years. Several conjunctive use programs are under study in the State today.

Currently, DWR, USBR, and local agencies are conducting planning studies for the Stanislaus River Basin and Calaveras River Water Use Program. The Stockton East Water District and the Central San Joaquin Water Conservation District have contracted for 155,000 af from New Melones Reservoir, a CVP facility on the Stanislaus River. The two districts propose to divert their contract water from the Stanislaus River during wet, above-average, and average years. During below-average, dry, and critical years the agencies would pump ground water to meet their needs and release their contract water down the Stanislaus River to provide increased flows for fish, water quality improvement in the south Delta channels, and increased yield to the SWP. The ground water basin would be replenished during wet years. A draft EIR/EIS is scheduled for release by fall 1994. Currently the effects of proposed Delta water quality and flow standards, implementation of the CVPIA, and Delta smelt and winter-run salmon biological opinions on this program are being evaluated.

DWR has also started investigations to identify conjunctive use projects in the Sacramento Valley which could further supplement SWP supplies. Initial studies are focused in eastern Yolo County, Butte County, and southern Sutter County. Other areas could be studied in the future, as agreements are reached with local agencies. Sacramento Valley conjunctive use programs could potentially augment drought year SWP supplies by as much as 100,000 af annually by the year 2000. These conjunctive use programs are in the early planning stages, and their yields are not included in SWP future supplies. (For more details about conjunctive use programs, see Chapter 4, *Ground Water Supplies.*)

Red Bank Project. The project, about 20 miles west of Red Bluff, would consist of two storage reservoirs, Dippingvat on the South Fork of Cottonwood Creek and Schoenfield on Red Bank Creek. The combined storage would be about 354,000 af and could produce an estimated 40,000 af of water supply benefit annually. The estimated cost of this project is $209 million. The project would provide increased water supply reliability for the SWP, increased flood protection along Cottonwood Creek and the Sacramento River, recreational opportunity, and anadromous fish restoration. The project is essentially on hold because of the uncertainty of Delta transfer facilities and escalating SWP costs.

Westside Sacramento Valley Storage and Conveyance Concept. This concept was first presented in Bulletin 3, *The California Water Plan,* published in 1957. The Westside storage and conveyance facilities, as envisioned by CH^2M Hill Engineering, would tie together Shasta, Clair Engle, and Oroville reservoirs and some proposed offstream reservoirs on the west side of the Sacramento Valley and would be operated for multiple uses including flood control, environmental, and water supply. A number of sites on the west side of the Sacramento Valley have been investigated for offstream reservoirs, including, among others, various sites on Cottonwood Creek, Stony Creek, Red Bank Creek, and Sites Reservoir (west of Maxwell). Under this option, a portion of the Sacramento River flood flows would be diverted and stored in offstream reservoirs for later use, thus reducing flood flows downstream.

A conveyance facility originating above Keswick Dam on the Sacramento River would convey water along the west side of the Sacramento Valley, and could be extended to Clifton Court Forebay in the South Delta. Anderson-Cottonwood Canal, Tehama-Colusa Canal, Glenn-Colusa Canal, Corning Canal, and a number of smaller Sacramento River diverters could be supplied by the Westside Canal. Under this option, Red Bluff Diversion Dam and major pumping plants and diversions along the Sacramento River could be removed, providing a free-flowing river from Keswick to the Delta. A cross-valley conveyance facility could also connect the Oroville complex with the Westside facility, to convey SWP water to the Banks Pumping Plant. The facility could deliver over 3 maf of CVP water to Sacramento Valley service areas, eliminating over 300 unscreened diversions along the Sacramento River. If the canal were extended to the Clifton Court Forebay, it would replace the isolated facility discussed in Chapter 10 (see Figure 11-13).

This option could greatly reduce the impact of diversions on the Sacramento River fishery; would improve conditions for Sacramento River fish migrations, thus enhancing the recovery of the winter-run chinook salmon; would begin the restoration of the Delta by reducing direct diversions and pumping from the Delta; and would provide additional water supply and good quality water for urban users.

CVP Water Supply Augmentation. The following options summarize the programs that could be investigated in the future or have been studied in the past, but are on hold for a variety of reasons. These programs could be reevaluated at any time to augment CVP supplies.

Central Valley Project Improvement Act Studies. This effort to identify elements of new yield totaling 800,000 af is just beginning, and no specifics are available.

Shasta Lake Enlargement. Both the USBR and DWR have studied enlarging Shasta Lake. Prior planning efforts looked at increasing the storage capacity by approximately 9.7 maf to a total capacity of 14.25 maf. This would require raising the existing dam approximately 213 feet. The enlargement would increase the firm yield to the SWP and CVP by 1.45 maf annually, and would cost about $4.5 billion. The enlargement would also provide instream flows for fish, increased flood protection on the Sacramento River, and provide greater amounts of dependable hydroelectric energy.

Some of the issues surrounding Shasta Dam enlargement are the inundation of significant cultural sites, environmental impacts, and relocations of I-5 and the Southern Pacific Railroad. Because of these issues and the high capital cost of construction, this project has been deferred indefinitely.

Clair Engle Lake Enlargement. An alternative to the Shasta Lake enlargement is enlarging Clair Engle Lake by raising Trinity Dam. The capital cost of this project would be less than the Shasta Lake Enlargement because of lower relocation costs. This option would raise Trinity Dam by about 200 feet to increase reservoir storage by about 4.8 maf (see Figure 11-13).

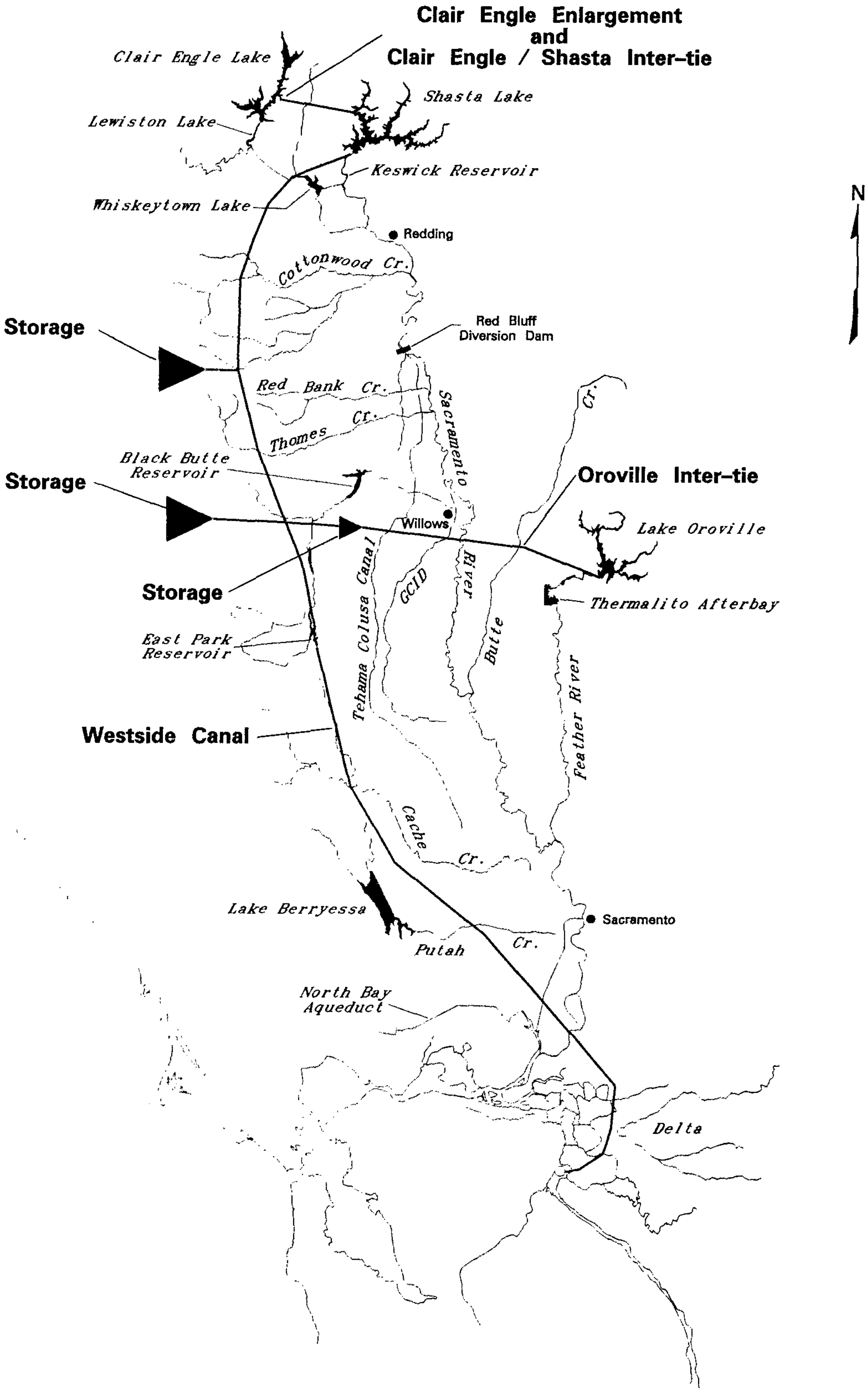
As envisioned by Harza Engineering Company, unregulated flood flows from the Sacramento River would be pumped to Clair Engle Lake through a pump/generation facility. Water would then be released to Shasta Reservoir to meet water needs during the dry season. Enlarging Clair Engle Lake would have a water supply benefit of about 700,000 af per year. Production of hydroelectric power during on-peak periods could provide revenues to help finance the project. The environmental impacts have not been identified.

Mid-Valley Canal. The USBR investigated options to provide supplemental water supplies to the east side of the San Joaquin Valley to improve the ground water overdraft problem. A *Report on the San Joaquin Valley Conveyance Investigation*, released in June 1990, identified the Mid-Valley Canal as the best option to develop a long-term solution to the valley overdraft problem.

The San Joaquin Valley Conveyance Investigation involves issues and activities affecting CVP water yield and project management. These include fish agreements and negotiations, the CVP Improvement Act of 1992, Delta point of diversion and rediversion under CVP water rights, consolidated place of use for CVP water rights, cross-Delta facilities, conveyance capacity south of the Delta, and the CVP water contracting program.

Because these unresolved issues will have an impact on the availability of a supplemental water supply for the canal, further work has been deferred on the San Joaquin Valley Conveyance Investigation.

Figure 11-13. Westside Sacramento Valley Storage and Conveyance Concepts



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Folsom South Canal Extension. Folsom South Canal originates at Nimbus Dam on the American River and extends southward toward San Joaquin County. The original plan was for a 68.8-mile-long canal, terminating about 20 miles southeast of the City of Stockton to deliver American River water to agricultural and urban contractors. The first two reaches of the canal were completed in 1973 to a point just south of State Highway 104. Construction of the three remaining reaches, a total of 42.1 miles, has been suspended pending completion and consideration of alternative studies.

American River Water Resources Investigation. A five-year study of water needs and water supply alternatives in the American River Watershed and adjacent counties began in 1991. The study is governed by a memorandum of agreement between USBR and the Sacramento Metropolitan Water Authority. Costs are shared on a fifty-fifty basis. Other local cost-sharing partners include the American River Authority, Sacramento County Water Agency, and San Joaquin County Flood Control and Water Conservation District. DWR is represented at the executive and management level and provides in-kind services. The study area includes portions of El Dorado, Placer, Sacramento, San Joaquin, and Sutter counties. The results of this study will be coordinated with early stages of design of the American River Flood Control Project, if authorized by Congress.

This study, under the leadership of the USBR, will evaluate alternatives for supplying unmet water demands in the study area. Included as alternatives are water transfers, conjunctive use, water conservation, and development of additional water supplies on the American River and other rivers in the study area. The feasibility report and environmental documentation for this study should be completed in 1996.

Local Water Supply Augmentation. Several possibilities for augmenting local water supplies are discussed below.

Gray Water Use. Gray water use could help reduce the demand for potable fresh water over the long term. Most households produce between 24 and 36 gallons of gray water per person per day. Many population centers in California are located in areas where the climate requires landscape irrigation at least seven months of the year, so gray water could replace potable water during that time span. Gray water would generally only be practical in larger lots where adequate side clearances can be maintained for subsurface irrigation fields.

A more substantial use of gray water in residential areas would require major investments in plumbing and may not be practical for existing housing. The expected population increase between 1990 and 2020 is about 19 million people. If half of these people live in single-family dwellings in new housing with gray water plumbing, the potential for gray water use, at 30 gallons per person per day, could be about 180,000 af of water in 2020.

Water Recycling. The WateReuse Association of California conducted a *Survey for Future Water Recycling Potential* (final report, July 1993). The survey indicates that there is potential for accelerating the pace of water recycling in the future. Statewide total water recycling could increase to about 1,691,000 af per year and create about 1,293,000 af of new water supply (see Table 11-7).

Level I total water recycling was estimated to be 1,321,000 af, producing about 923,000 af of new supply. The remainder would be Level II water recycling. Therefore, there is a potential for 370,000 af of additional water recycling per year by 2020, which should be investigated under Level II options.

Water Desalting. Engineers and scientists have been working on economical ways to desalt water for the last fifty years. The major limitation of desalting has been its

Table 11-11. Annual 1990 and Potential Future Water Desalting
(thousands of acre-feet)

Type of Desalting	*1990*	*2000*	*2010*	*2020*
Recycled Water	5.6	33.6	33.6	33.6
Sea Water	11.4	149.4	259.4	369.4
TOTAL	17	183	293	403

high cost, much of which is directly related to high energy requirements. A recent, principal development is the availability of relatively low cost desalting systems for reclaiming brackish (low-salinity) ground water (ground water reclamation) and for recycling municipal water. Both ground water reclamation and desalting of recycled municipal water are being successfully practiced in California and are projected to grow. The cost of desalting using these systems can range from $300 to $500 per acre-foot (plus other costs of treatment in the case of water recycling). Ground water reclamation is discussed in this chapter under *Level I—Reliability Enhancement Options*.

Sea water desalting costs from $900 to $2,000 per acre-foot; additional costs are required to convey the water to the place of use. With few exceptions, the combined costs are greater than obtaining water from most other sources. However, sea water desalting can be a feasible option for coastal communities that are relatively far from the statewide water distribution system and have limited water supplies. Because of such circumstances, sea water desalting plants have been constructed in the City of Avalon (Santa Catalina Island) and the Cities of Santa Barbara and Morro Bay in the Central Coast Region. Sea water desalting plants can be designed to operate only during droughts to improve water supply reliability. They can also be downsized and operated continuously in conjunction with ground water (reducing ground water pumping during wet periods and providing more ground water supplies for drought periods). The reliability of supply is very high, although at a generally higher cost.

Future desalting programs depend on several factors including the success of pilot projects, the determination of environmental requirements for concentrate disposal and, most importantly, the availability and cost of other sources of supply. Table 11-11 shows current and potential desalting volumes by type of desalting. Because of its relatively high costs and uncertain future, desalting is considered a Level II option for future water supply. Its use is not likely to be widespread and, therefore, is not included in water supply projections and the water budget in this report. The potential desalting water supply production shown in Table 11-11 was derived from various feasibility studies in the last five years, and the amounts represent a potential for Level II future supply as other water sources become unavailable or too costly. The increasing potential for sea water desalting represents future additions of desalting systems to existing power plants during refurbishment and repowering projects. This combination of power generation and desalting is generally the most cost-effective form for sea water desalting facilities. Metropolitan Water District of Southern California and San Diego County Water Authority, in conjunction with San Diego Gas and Electric Company, are among the utilities considering such projects.

Reuse of Brackish Agricultural Drainage Water. Agricultural drainage is reused extensively throughout the State. As drainage water is reused, its salinity can be increased to a level that prohibits further reuse for most crops. Some salt-tolerant crops can be grown with a portion of applied water having a relatively high concentration of dissolved solids. Fresh water use might be reduced by substituting brackish agricultural drainage water or brackish shallow ground water for irrigation during the mid- and late growing season. Using drainage water for irrigation of some salt-tolerant crops was studied and discussed in the San Joaquin Valley Drainage Program report, *A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley*.

The primary concern in long-term use of brackish drainage water for irrigation is the impact of salt accumulation on the integrity and productivity of the soil. Before a decision can be made about large-scale reuse of brackish agricultural drainage water for irrigation, field-sized pilot experiments should be conducted during the next decade to examine the impact of salt accumulation on soil and the feasibility of commercial farming with brackish water.

Local Conjunctive Use Programs. Local agencies are also considering conjunctive use of surface and ground water supplies to enhance reliability of their supplies. Calleguas Municipal Water District, through a cooperative agreement with MWDSC, is pursuing the development of a large-scale conjunctive use project in the North Las Posas Basin in Ventura County. This project could provide storage of up to 300,000 af of imported water. When available, water would be injected into the ground water basin and subsequently recovered as demand dictates.

San Diego County Water Authority Water Resources Plan and Emergency Water Storage Project. The San Diego County Water Authority has recently completed a Water Resources Plan which identifies future water demands, reviews water supply options, and recommends a preferred mix of future supplies. This preferred mix will guide the authority in securing adequate water supplies to meet future demands. The plan includes the development of an additional 85,000 af of local supplies by 2010. These supplies include sources such as water recycling, ground water development, and brackish water desalination. Also, an estimated 70,000 af per year of conservation resulting from implementation of urban BMPs is included in the plan. Currently the authority receives less than ten percent of its average water supply from local sources, or about 60,000 af per year.

The county relies on water imported from MWDSC via the California and the Colorado River aqueducts. However, the imported water supply pipelines cross three major earthquake faults and the flood-prone San Luis Rey River. Currently, San Diego County's 105,000 af of emergency storage is considered inadequate. The latest population growth projections indicate that the county will need as much as 100,000 af in increased storage capacity by 2030. The SDCWA is also studying to determine the best method for meeting the county's emergency water storage needs; the project's goal is to provide sufficient water storage capacity so the county can endure up to a six-month supply interruption without severe economic and environmental damage.

The objective of the current study is to identify combinations of various elements that are capable of meeting the requirements for emergency storage. Each system alternative may be composed of any or all of the following elements: construction of new or enlargement of existing surface reservoirs, emergency reoperation of existing reservoirs, and new pipeline facilities. There are currently thirteen primary storage systems being considered, including expansion and reoperation of San Vicente Reservoir, reoperation of El Capitan Reservoir, and potential construction of Mossa Canyon, Geujito Valley, or Olivenhain reservoirs. The reoperation scenario consists of reconfiguring and enlarging the existing distribution system so that pipelines can shift water among the existing reservoirs in the county.

The reservoir sites and reoperation of existing facilities can be combined in many different systems to meet the county's emergency storage needs. The study review process is designed to select the least environmentally damaging, most practicable system alternatives.

Santa Clara Valley Water District Investigation. Santa Clara Valley Water District is currently investigating various ways of providing additional drought year supplies for its service area. Investigations include increased water conservation programs (to reduce demand), water reclamation, permanent water transfers, and additional long-term storage. Existing facilities and contracts can meet current and future demands during average years through the year 2020. Additional supplies are needed to meet the district's demand during drought periods. Projected drought year deficiencies are approximately 125,000 af annually.

Other Water Management and Supply Augmentation Options. Other options could include watershed management, local rainfall collection and storage, and ground water recharge with storm water. Potential water supply management benefits from implementing watershed management in national forests could be about 100,000 af statewide. There is also some potential for watershed management on lands other than those owned by the U.S. Forest Service. Small local rainfall collection and storage facilities are used for water supplies in remote areas, such as Point Reyes Lighthouse, and in Southern California to fill fire-fighting water tanks on ridge tops. Supply from this option is relatively expensive.

Cracked earth near Naciemiento Reservoir in San Luis Obispo County. During the 1987–92 drought, part of the Central Coast Region endured unprecedented water shortages; Santa Barbara County fared the worst. The region's population is expected to increase about 56 percent, to more than 2 million people by 2020.

Chapter 12

Water Supply and Demand Balance

Benjamin Franklin wrote in *Poor Richard's Almanack*, "When the well's dry, we know the worth of water." This simple truism embodies the key to determining the value of water—the scarcer it is, the more valuable. Furthermore, the consequences of poor quality water or deficient supplies can range from minor inconveniences to damaging economic and environmental effects. In extreme cases, the consequences endanger human health. Water must be available in the quantity and quality expected for stability, productivity, growth, and a healthy environment. The water supply must be reliable to achieve these ends.

The term *reliability*, as used in the day-to-day planning and management of California's water resources, is a measure of a water service system's expected success in managing shortages, without detrimental effects, and providing a supply that meets expected demands. It is not strictly a characteristic of water supply because it includes demand management and any actions, such as emergency water allocation programs during drought years, that can mitigate the effects of shortages. Given this definition, California essentially had an adequate average annual developed supply that could meet the 1990 level urban, agricultural, and environmental water demands. However, the actual 1990 drought experience found many California communities and the environment suffering from a somewhat less-than-reliable drought supply to meet drought year needs.

This water plan update presents two water supply and demand scenarios to best illustrate overall demand and supply availability. An average year and a drought year are presented for the 1990 level of development and for projections to 2020. Shortages

California's Water Supply Availability

Average year supply is the average annual supply of a water development system over a long period. For this report the SWP and CVP average year supply is the average annual delivery capability of the projects over a 70-year study period (1922-91). For a local project without long-term data, it is the annual average deliveries of the project during the 1984-86 period. For dedicated natural flow, it is the long-term average natural flow for wild and scenic rivers, or it is environmental flows as required for an average year under specific agreements, water rights, court decisions, and congressional directives.

Drought year supply is the average annual supply of a water development system during a defined drought period. For this report, the drought period is the average of water years 1990 and 1991. For dedicated natural flow, it is the average of water years 1990 and 1991 for wild and scenic rivers, or it is environmental flows as required under specific agreements, water rights, court decisions, and congressional directives.

shown under average conditions are chronic shortages indicating the need for additional long-term water management measures. Shortages shown under drought conditions can be met by both long-term and short-term measures, depending on the frequency and severity of the shortage and water service reliability requirements.

This chapter presents 1990 level and future water needs to 2020 and balances them with supplies from existing facilities and water management programs, along with future demand management and water supply augmentation options (the California Water Budget). Future water management options are presented in two levels to better reflect the status of investigations required to implement them.

- Level I options are those programs that have undergone extensive investigation and environmental analyses and are judged to have a higher likelihood of being implemented by 2020.
- Level II options are those programs that could fill the remaining gap shown in the balance between supply and urban, agricultural, and environmental water demands. These options require more extensive investigation and alternative analyses.

Recommended actions follow the California Water Budget. Implementation of these actions must be undertaken as part of a water resource management program to restore the health of our rivers and aquatic species while making our water supply infrastructure more reliable. A discussion of the economic costs of unreliability ends this chapter.

Water Supply

California should be able to meet its future water service reliability needs through a variety of water management actions designed to supplement, improve, and make better use of existing systems while protecting and enhancing the aquatic environment. Level I and Level II demand management and supply augmentation options include increased water conservation, expanded conveyance system capabilities, additional storage facilities, additional water recycling, more reliance on conjunctive use of ground water basins, and increasing the use of water transfers and water banking. The following sections summarize the benefits of existing water management programs and future Level I and Level II water management options that can be implemented to meet California's water service reliability needs.

Existing Water Management Programs

Table 12-1 shows California's water supply with existing facilities and programs. (Supplies from the Delta were calculated under D–1485 operating criteria.) The 1990 level average annual supply is about 63.5 million acre-feet (including natural flows dedicated for instream use) and could decrease to 63.0 maf by 2020 without ground water overdraft or any additional facilities or programs. A possible substantial reduction in Colorado River supplies could be offset largely by short-term transfers and increased SWP Delta diversions. The 1990 level annual drought year supply is about 50.5 maf and could decrease to 49.3 maf by 2020 without additional storage and water management options. Note that supplies shown under D–1485 for Delta exports do not take into account: (1) 800,000 af of CVP water now dedicated to environmental needs pursuant to the CVPIA, and (2) recent and proposed actions to protect aquatic species in the Delta. As a result of these actions, urban and agricultural water supplies are overstated.

Annual reductions in total water supply for urban and agricultural uses could be in the range of 500,000 af to 1 maf in average years and 2 to 3 maf in drought years.

Table 12-1. California Water Supplies with Existing Facilities and Programs
(Decision 1485 Operating Criteria for Delta Supplies)
(millions of acre-feet)

Supply	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
Surface								
Local	10.1	8.1	10.1	8.1	10.2	8.3	10.3	8.4
Local imports(1)	1.0	0.7	1.0	0.7	1.0	0.7	1.0	0.7
Colorado River	5.2	5.1	4.4	4.4	4.4	4.4	4.4	4.4
CVP	7.5	5.0	7.7	5.1	7.7	5.2	7.7	5.2
Other federal	1.2	0.8	1.3	0.8	1.3	0.8	1.3	0.8
SWP(1)	2.8	2.1	3.2	2.0	3.3	2.0	3.3	2.0
Reclaimed	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ground water(2)	7.1	11.8	7.1	12.0	7.2	12.1	7.4	12.2
Ground water overdraft(3)	1.3	1.3	—	—	—	—	—	—
Dedicated natural flow	27.2	15.3	27.4	15.4	27.4	15.4	27.4	15.4
TOTAL	63.5	50.4	62.4	48.9	62.7	49.1	63.0	49.4

(1) 1990 SWP supplies are normalized and do not reflect additional supplies delivered to offset the reduction of supplies from the Mono and Owens basins to the South Coast hydrologic region.
(2) Average ground water use is prime supply of ground water basins and does not include use of ground water which is artificially recharged from surface sources into the ground water basins.
(3) The degree future shortages are met by increased overdraft is unknown. Since overdraft is not sustainable, it is not included as a future supply.

These reductions result mainly from compliance with the ESA biological opinions and proposed EPA Bay-Delta standards. While these impacts do not consider the potential reductions in Delta exports due to "take limits" under the biological opinions, they basically fall within the 1-to-3-maf range for proposed additional environmental demands included in the California Water Budget.

The largest single source of water supply in California is ground water. On average, ground water provides about 15 maf of applied water annually. However, because of deep percolation and extensive reuse of applied surface and ground water, current average annual net ground water use is about 8.4 maf, including about 1.3 maf of ground water overdraft. In drought years, the net use of ground water increases significantly to 13.1 maf (including overdraft), which indicates the importance of the State's ground water basins as storage facilities to meet drought year water needs.

Annual ground water overdraft in 1990 was reduced by about 0.7 maf from the 1980 level of 2 maf. The reduction is mostly in the San Joaquin Valley and is due primarily to the benefits of imported supplies to the Tulare Region and construction and operation of new reservoirs in the San Joaquin Region during the 1960s and 1970s. However, until solutions to complex Delta problems are identified, the reductions in overdraft seen in the last decade in the San Joaquin Valley will reverse as more ground water is pumped to make up for lost surface water supplies from the Delta.

Level I Water Management Options

Water managers are looking into a wide variety of water management actions to supplement, improve, and make better use of existing resources. The single most important action will be solving key issues in the Delta. The challenge is to continue to explore new and innovative water management methods while implementing various programs and facilities to meet the water demands of the State's growing population, agriculture, and the environment. Level I demand management and water supply management options are described in detail in Chapter 11.

The following sections summarize the water supply benefits of Level I Water Management Programs. The contribution of these programs to future California water supplies is included in Table 12-2. Level I options could contribute up to an additional 1.6 maf in an average year by the year 2020. The drought year contribution could be an additional 4.1 maf by 2020. Most of the increase would be through new State and local facilities and programs as summarized below.

Demand Management Programs. These programs are designed to reduce long-term demand for water (water conservation and land retirement), or to manage supplies during short-term drought conditions (mandatory conservation and land fallowing) to ensure water service for critical needs. Critical needs include maintaining public health and safety, providing for industrial and commercial uses, preserving permanent crops such as trees and vines, saving high investment crops such as cut flowers and nursery products, and ensuring the survival of fish and wildlife.

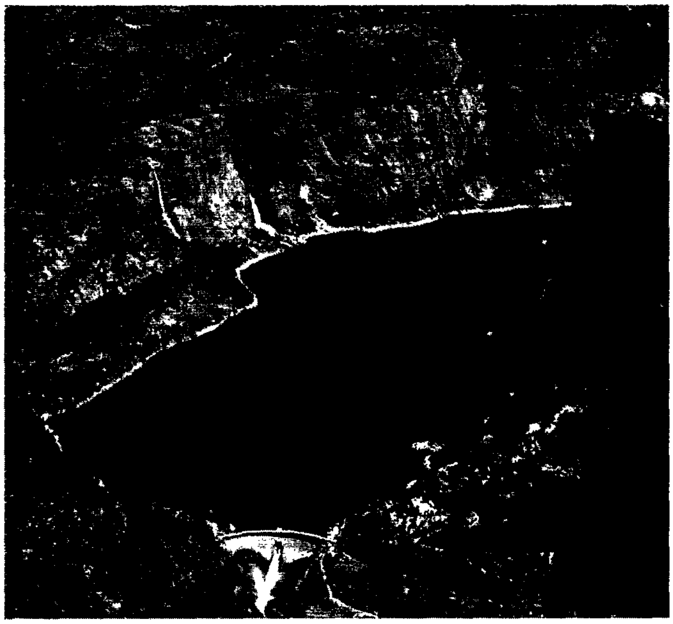
Level I urban water conservation, through implementation of urban Best Management Practices, could reduce urban applied water by 1.3 maf and reduce net water demand by 0.9 maf by 2020. Level I agricultural water conservation, through increased irrigation efficiencies and implementation of Efficient Water Management Practices, could reduce agricultural applied water by 1.7 maf and reduce net water demand by 0.3 maf by 2020. Agricultural land retirement of 45,000 acres (primarily lands with poor drainage disposal conditions) under Level I could further reduce agricultural net water demand by 0.15 maf by 2020.

Short-term demand management options during periods of drought, such as demand reduction through urban rationing programs, could reduce net water demands by 1.0 maf. The urban rationing program is illustrative of a 10-percent shortage

Table 12-2. California Water Supplies with Level I Water Management Programs
(Decision 1485 Operating Criteria for Delta Supplies)
(millions of acre-feet)

Supply	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
Surface								
Local	10.1	8.1	10.2	8.2	10.2	8.3	10.3	8.4
Local imports(1)	1.0	0.7	1.0	0.8	1.0	1.0	1.0	1.0
Colorado River	5.2	5.1	4.4	4.4	4.4	4.4	4.4	4.4
CVP	7.5	5.0	7.7	5.2	7.7	5.2	7.7	5.2
Other federal	1.2	0.8	1.3	0.8	1.3	0.8	1.3	0.8
SWP(1)	2.8	2.1	3.4	2.1	3.9	3.0	4.0	3.0
Reclaimed	0.2	0.2	0.7	0.7	0.8	0.8	0.9	0.9
Ground water(2)	7.1	11.8	7.1	11.9	7.2	12.2	7.3	12.3
Ground water overdraft(3)	1.3	1.3	—	—	—	—	—	—
Dedicated natural flow	27.2	15.3	27.5	15.4	27.5	15.4	27.5	15.4
TOTAL	63.5	50.4	63.3	49.5	64.0	51.2	64.5	51.6

(1) 1990 SWP supplies are normalized and do not reflect additional supplies delivered to offset the reduction of supplies from the Mono and Owens basins to the South Coast hydrologic region.
(2) Average ground water use is prime supply of ground water basins and does not include use of ground water which is artificially recharged from surface sources into the ground water basins.
(3) The degree future shortages are met by increased overdraft is unknown. Since overdraft is not sustainable, it is not included as a future supply.



Hetch Hetchy Reservoir, in Tuolumne County, stores up to 360,000 acre-feet for customers in the San Francisco Bay area. The area suffered significant water shortages during the 1987-92 drought. In 1991, after two years of well-below-normal supplies, customers had to reduce indoor water use by 10 percent and outdoor use by 60 percent.

for drought events that could occur about once every 20 years. During less frequently occurring and more severe droughts (that is, an event that occurs once every 100 years), much greater shortages would occur, causing substantial economic impacts on urban and agricultural areas and environmental impacts on fish and wildlife.

Rationing becomes less effective and more costly over time because of the implementation of long-term institutionalized conservation practices, such as the urban BMPs. Accounting for this phenomenon of demand hardening is critical to the determination of shortage costs. A 10-percent shortage is used to illustrate the Level I option. Planning for such drought rationing programs must include evaluation of the cost of shortages versus the cost of providing the supply. Further, drought rationing programs will vary from region to region depending on each region's water service reliability needs. See Chapter 11 for a full discussion of these Level I options.

Local Agency Programs. Local water management programs are designed to augment both average and drought year supplies, with some programs primarily providing drought year supplies. Water reclamation (including water recycling and ground water reclamation) is expected to increase local average and drought year supplies by about 0.8 maf per year by 2020 (the 1990 level of water recycling is about 0.2 maf per year). Other Level I local water management programs under study could improve local drought supplies by about 0.3 maf annually by 2020. These programs include additional supplies planned by the Metropolitan Water District of Southern California from construction of Domenigoni Valley Reservoir, East Bay Municipal Utility District's water management program, Monterey Peninsula Water Management District's construction of New Los Padres Reservoir on the Carmel River, City of San Luis Obispo's Salinas Reservoir enlargement, and benefits from El Dorado County Water Agency's water resources development and management program. The water supply of Contra Costa Water District's Los Vaqueros Reservoir and the CVP portion of El Dorado County Water Agency's water management program are accounted for under existing CVP supplies.

Offsetting some of the supply improvements to the South Coast Region are actions that reduce reliability of existing supplies. The City of Los Angeles has historically imported a major portion of its supply from the Mono-Owens basin in the South Lahontan Region. Export of water from these basins has been the subject of litigation since the early 1970s. In 1972, the County of Inyo filed suit against the City of Los Angeles claiming that increases in ground water pumping for export were harming the Owens Valley environment. The parties recently reached agreements on the long-term ground water management plan for the Owens Valley. Flow diversions from Mono Basin also have been the subject of extensive litigation. The Los Angeles Department of Water and Power is now prohibited by court order from diverting from Mono Lake tributaries until the lake level stabilizes at 6,377 feet above sea level. These lawsuits, together with the impact of the recent drought, resulted in an estimated reduction of over 0.3 maf in 1990 exports from the basins by LADWP. Due to these reductions in imported supplies from Mono and Owens basins, LADWP increased its request for supplemental water supplies from MWDSC. As a result, MWDSC increased its request for deliveries of SWP supplies, thus increasing its demand for Delta supplies.

In addition, California in recent years has received about 5 maf of Colorado River water annually, including about 0.8 maf of surplus or unused water. As Arizona and the states in the Upper Colorado River Basin increase the use of their apportionments, the availability of surplus supplies for California will be diminished. This will also affect supplies in the Colorado River Region, but will have the greatest impacts on imports to the South Coast Region. MWDSC is looking to water conservation and land fallowing programs to maintain its Colorado River supplies. (See the following section on water marketing and transfers.)

State Water Project Programs. With existing facilities and SWRCB D-1485 operating criteria, average annual SWP supplies could increase from the 1990 level of 2.8 maf to 3.3 maf by 2020 due to increased demand in the SWP service areas. This possible increase reflects the ability to maximize the diversion capability of the SWP that was possible with existing facilities operated under SWRCB D-1485. SWP 1990 level drought year annual supplies, without additional facilities, is about 2.1 maf (based on 1990-91 drought conditions) and would decrease to about 2.0 maf by 2020. However, recent and future actions to protect aquatic species in the Delta will greatly limit SWP export capability from the Delta, thus reducing the reliability of existing SWP supplies, the feasibility of additional storage facilities, and the ability to transfer water until solutions to complex Delta problems are identified and put into place. (See Chapter 10 for a review of Delta problems.)

Average annual SWP delivery capability could increase from the 1990 level of 2.8 maf to about 4.0 maf in 2020 with additional Level I facilities to augment SWP supplies (under D-1485 criteria). These programs include the South Delta Water Management programs, long-term Delta facilities, the Kern Water Bank (including Local Elements), and the Los Banos Grandes Facilities. These projects, which are included as Level I

Table 12-3. State Water Project Supplies
(millions of acre-feet)

Level of Development	SWP Delivery Capability[1]				SWP Delta Export Demand
	With Existing Facilities		With Level I Water Management Programs[2]		
	average	drought	average	drought	
1990	2.8	2.1	—	—	3.0
2000	3.2	2.0	3.4	2.1	3.7
2010	3.3	2.0	3.9	3.0	4.2
2020	3.3	2.0	4.0	3.0	4.2

(1) Assumes D-1485. SWP capability is uncertain until solutions to complex Delta problems are implemented and future actions to protect aquatic species are identified. Includes SWP conveyance losses.
(2) Level I programs include South Delta Water Management Programs, long-term Delta Water Management Programs, the Kern Water Bank (including Local Elements), and Los Banos Grandes facilities.
Note: Feather River Service Area supplies are not included. FRSA average and drought supplies are 927,000 and 729,000 AF respectively.

options, have been planned in significant detail, including environmental impact assessments. As planning is finalized, implementation of these projects is authorized under existing DWR authority and financing. Table 12-3 shows the projected SWP delivery capability and SWP water demands. By the year 2020 the annual SWP contractor demand on the SWP would be about 4.2 maf. SWP average annual delivery capability, with additional facilities, would be about 4.0 maf, just short of meeting contractor water demands in average years. In drought years, the 2020 supplies would be reduced to 3.0 maf, reflecting the severity of the 1990 and 1991 drought event.

Central Valley Project Programs. CVP exports from the Delta through the Tracy Pumping Plant will not increase above historical levels because of existing pumping limitations. Future increases in CVP deliveries to the San Joaquin and San Francisco Bay regions would be primarily from increased Delta supplies to the Contra Costa Water District and supply development from New Melones Reservoir in the San Joaquin Region.

CVP deliveries to urban contractors north of the Delta could increase as urban demand increases with existing CVP facilities. Supplies will most likely come from any presently developed surplus that may exist and from reallocation of existing CVP supplies. The CVP Improvement Act of 1992 and recent actions to protect aquatic species greatly affect current and future CVP operations and the reliability of its supplies. The USBR is preparing a programmatic EIS to implement provisions of the CVPIA.

The USBR is required by the CVPIA to find replacement sources for 800,000 af of water recently allocated to environmental uses. The 1990 level CVP supplies for average and drought years were about 7.5 maf and 5.0 maf respectively, and are expected to increase slightly to 7.7 maf and 5.2 maf by 2020 under D-1485 criteria. However, recent endangered species actions will greatly affect the feasibility of additional CVP storage facilities until solutions to complex Delta problems are identified and put into place.

Water Marketing and Transfers. Water marketing and transfers can significantly increase the reliability of drought year supplies for some agricultural and urban areas and the environment. Such short-term transfers most often result in a reallocation of existing supplies, by either temporary (spot market) or long-term agreements. Sources of transfer water include reserve surface supplies, conjunctive use of ground water, and water made available by agricultural land fallowing. The contribution of such water transfers among willing sellers and buyers could be 0.6 maf or more during drought years (as experienced in 1991), depending on location of the source and availability of short-term drought transfers capacity in conveyance systems. Based on recent MWDSC actions to secure additional Colorado River supplies, it is estimated that there is a 0.2-maf potential for Level I transfer from the Colorado River Region to the South Coast Region. (Chapter 11 presents a discussion of water transfer limitations.) Drought water transfer operations similar to the 1991 and 1992 State Drought Water Bank are being planned to lessen drought impacts in the future.

Although water transfers are expected to significantly reduce overall economic impacts of droughts, from a statewide demand and supply perspective, water marketing would not significantly augment long-term average annual water supplies. Long-term transfers (ones that require supplies to be transferred every year, not only during drought years) are limited by available capacity in the major transportation and conveyance systems which are normally used at capacity during wet and average years. Nevertheless, transfer programs such as the IID-MWDSC agreement, which provides conserved IID water for transfer to the MWDSC service area by using available capacity in the Colorado River Aqueduct, will contribute to the State's long-term water supplies.

Total usable transfer capacity of existing major conveyance facilities from the Delta, under D-1485, during drought years is about 1.4 maf per year. Level I drought water transfers from the Delta are estimated at 0.6 maf, resulting in a remaining Level II transfer potential of about 0.8 maf. The unused capacity of conveyance facilities is considerably less during average years when both projects would be able to export more of their own water. However, recent actions taken to protect fisheries in the Delta have considerably curtailed the pumping capability of the projects through limitations placed on operations of SWP and CVP facilities to convey or wheel water-transfer water. The 1990 drought year usable transfer capacity of the SWP and CVP is estimated to be about 0.7 maf when the projects are operated to comply with Delta smelt and winter-run salmon 1993 biological opinions.

Level II Water Management Options

There are a number of Level II water management options requiring more extensive investigation and alternative analyses that could either further reduce demand or augment supplies to meet remaining demands to 2020. Level II water management programs are not inclusive of all available future options, but rather a starting point to begin investigations to fill the remaining gap shown in the balance between supply and urban, agricultural, and environmental demands. Chapter 11 presents a more extensive discussion of Level II options.

Water Demand

California's estimated total net demand for water at the 1990 level of development was 63.5 maf for the average year scenario and 53.2 maf for the drought year scenario. Urban and agricultural demands are discussed in detail in Chapters 6 and 7 respectively. Environmental water demands are existing instream flow requirements, wild and scenic river flows, Bay-Delta protection requirements under SWRCB D-1485, and supplies for managed fresh water wetlands. Potential increases in environmental water demands are broken down into hypothetical Cases I through III (1 to 3 maf), representing the envelope or range of potential and uncertain environmental water demands that have immediate and future consequences on supplies available from the Delta, beginning with actions taken in 1992 and 1993 to protect winter-run salmon and Delta smelt (actions that could also indirectly protect and enhance conditions for other aquatic species) and water dedicated to environmental needs in the CVPIA. Environmental water needs are discussed in Chapter 8.

Table 12-4 shows the urban, agricultural, and environmental water demand for 1990 through 2020. Note that the net water demand is usually much less than applied water, because of the extensive reuse that takes place within a basin. Factors affecting California's water demand are briefly discussed below.

Water conservation effects on net water demand vary greatly, depending on the opportunity for water reuse within an area. Effective water conservation in a region is the reduction in depletion, which is defined as reduction of the evapotranspiration of applied water, irrecoverable losses from a distribution system, and outflow to a salt sink. For example, in the Sacramento River Region water is reused extensively, so the potential for effective conservation is limited, but a large water savings potential exists in the coastal and Colorado River regions, where excess applied water generally enters saline sinks (for example, the Salton Sea or the Pacific Ocean) or saline ground water basins and cannot be economically reused.

Reductions in applied water can often be beneficial because they reduce the pumping and treatment costs for urban uses and could reduce overall diversions from streams and rivers to benefit fish and wildlife. However, care must be taken to look at impacts on downstream reuse such as other farms or wetlands that rely on excess applied water for their supplies.

Average demand for water for the 1990 level of development is normalized. Normalization of agricultural net water demand is based on adjusted irrigated acreages due to changes in crop markets, government intervention (farm programs), and the effect of annual hydrologic conditions on water use, such as drought. Normalization of urban water demand is based on adjusted per capita use to take into account the impact of the drought on urban water use (see Chapters 6 and 7).

Unit water demand during drought years increases because crops and landscapes require more irrigation earlier in the season to replace lost precipitation. However, insufficient supplies force demand management measures, such as more intensive irrigation management, water rationing, and land fallowing. These measures help reduce the actual water use during extreme drought, but overall demand for water during drought periods is generally greater than average.

California's annual net water demands in 2020 are projected to reach 65.7 maf in average years and 55.3 maf in drought years. With the range of 1 to 3 maf for proposed additional environmental water demands, California's annual net water demand could increase to 66.7 to 68.7 maf in average years and 56.3 to 58.3 maf in drought years.

Table 12-4. California Water Demand
(millions of acre-feet)

Category of Use	*1990*		*2000*		*2010*		*2020*	
	average	*drought*	*average*	*drought*	*average*	*drought*	*average*	*drought*
Urban								
Applied water demand	7.8	8.1	9.3	9.7	10.9	11.4	12.7	13.2
Net water demand	6.8	7.1	7.9	8.3	9.2	9.6	10.5	11.0
Depletion	5.7	6.0	6.4	6.7	7.3	7.7	8.4	8.8
Agricultural								
Applied water demand	31.1	32.8	30.2	31.9	29.4	31.1	28.8	30.4
Net water demand	26.8	28.2	26.1	27.4	25.4	26.7	24.9	26.1
Depletion	24.2	25.6	23.7	25.1	23.2	24.6	22.8	24.1
Environmental								
Applied water demand	28.8	16.8	29.3	17.3	29.3	17.3	29.3	17.3
Net water demand	28.4	16.4	28.8	16.8	28.8	16.8	28.8	16.8
Depletion	24.4	12.9	24.7	13.3	24.7	13.3	24.7	13.3
Other(1)								
Applied water demand	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Net water demand	1.5	1.5	1.5	1.4	1.5	1.4	1.5	1.4
Depletion	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TOTAL								
Applied water demand	68.0	58.0	69.1	59.2	69.9	60.1	71.1	61.2
Net water demand	63.5	53.2	64.3	53.9	64.9	54.5	65.7	55.3
Depletion	55.3	45.5	55.8	46.1	56.2	46.6	56.9	47.2

(1) Includes major conveyance facility losses, recreation uses, and energy production.

These demand projections include the effects of existing and future urban and agricultural water conservation efforts to reduce applied and net water demand.

Urban Water Use

California's population is projected to increase to 49 million people by 2020 (from about 30 million in 1990) and even with extensive water conservation, urban annual net water demand will increase by about 3.7 maf. Nearly half of the increased population is expected to occur in the South Coast Region, increasing that region's annual urban water demand by 1.8 maf (see Chapter 6).

Agricultural Water Use

Irrigated agricultural acreage is expected to decline by nearly 400,000 acres, from the 1990 level of 9.2 million acres to a 2020 level of 8.8 million acres, representing a 700,000-acre reduction from the 1980 level. Reductions in projected irrigated acreage are due primarily to urban encroachment onto agricultural land and land retirement in the western San Joaquin Valley where poor drainage and disposal conditions exist. Increases in agricultural water use efficiency, combined with reductions in agricultural acreage and shifts to growing lower-water-use crops are expected to reduce agricultural annual net water demand by about 1.9 maf by 2020 (see Chapter 7).

Environmental Water Use

The 1990 level and projections of environmental water needs include water needs of managed fresh water wetlands (including increases in supplies for refuges resulting from implementation of the CVPIA), instream fishery requirements, Delta outflow, and wild and scenic rivers. Average annual net water demand for environmental needs is expected to increase by 0.4 maf by 2020. Environmental water needs during drought years are considerably lower than average years, reflecting principally the variability of natural flows in the North Coast wild and scenic rivers. Furthermore, regulatory agencies have proposed a number of changes in instream flow needs for major rivers, including the Sacramento and San Joaquin. These proposed flow requirements are not additive; however, an increase from 1 to 3 maf is presented to envelop potential environmental water needs as a result of proposed additional instream needs and actions under way by regulatory agencies, both of which benefit fisheries (see Chapter 8).

California Water Balance

The California Water Budget, Table 12-5, compares total net water demand with supplies from 1990 through 2020. (Delta supplies assume SWRCB's D-1485 operating criteria without endangered species actions.) Average annual supplies for the 1990 level of development were generally adequate to meet average demands. However, during drought, 1990 level supplies were insufficient to meet demand, which results in a shortage of over 2.7 maf under D-1485 criteria in 1990. In drought years 1991 and 1992, these shortages were reflected in urban mandatory water conservation, agricultural land fallowing and crop shifts, reduction of environmental flows, and short-term water transfers.

The forecasted 2020 net demand for urban, agricultural, and environmental water needs amounts to 65.7 maf in average years and 55.3 maf in drought years, after accounting for future reductions of 1.3 maf in net water demand due to increased water conservation efforts (resulting from implementation of urban BMPs, agricultural EWMPs, and increased agricultural irrigation efficiencies (discussed in Chapters 6 and 7) and another 0.1-maf reduction due to future land retirement. It should be noted that several pending actions to protect and restore fisheries could require additional environmental water in the range of 1 to 3 maf. These actions include:

- Biological opinions for the winter-run salmon and Delta smelt, which place operational constraints on Delta exports and vary yearly.
- Implementation of the CVPIA: reallocation of 800,000 af of annual CVP supplies for environmental use in the Central Valley streams, about 120,000 af of additional flow in the Trinity River, and about 200,000 af for wetlands.
- EPA's proposed Bay-Delta standards: the total impacts on urban and agricultural water supplies will not be known until final standards are adopted sometime in 1994 and later implemented.
- SWRCB water quality control plan for the Bay-Delta and subsequent water right proceedings: In March 1994, SWRCB began a series of workshops to review Delta protection standards and examine proposed EPA standards. The total impacts on water supply for urban and agricultural use will not be known until a final plan is adopted and the water rights proceedings are completed.

Considering that much of the hypothetical range for additional environmental water has now been mandated or formally proposed by the above actions, California is now facing the more frequent and severe water supply shortages forecasted for the year 2000 and beyond. In 1993, an above-normal year, some CVP contractors had their supplies reduced by 50 percent. These unanticipated shortages point to the need for a quick resolution of Delta problems, through federal cooperation and participation, and the need to move forward with demand management and supply augmentation programs at both the State and local levels.

By 2020, without additional facilities and improved water management, an annual shortage of 3.7 to 5.7 maf could occur during average years, again depending on the outcome of the various actions listed above. This shortage is considered chronic and indicates the need for implementing long-term water supply augmentation and management measures to improve water service reliability. Similarly, by 2020, annual drought year shortages could amount to 7 to 9 maf under D-1485 criteria, also indicating the need for long-term measures.

However, water shortages would vary from region to region and sector to sector. For example, the South Coast Region's population is expected to increase to over 25 million people by 2020, requiring an additional 1.8 maf of water each year. Population growth and increased demand, combined with a possibility of reduced supplies from the Colorado River, mean the South Coast Region's annual shortages for 2020 could amount to 0.4 maf for average years and 0.8 maf in drought years; this is before consideration of the additional 1-to-3-maf environmental water needs, which could reduce existing SWP supplies from the Delta. Thus, projected shortages could be larger if solutions to complex Delta problems are not found and implemented along with proposed local water management programs and additional facilities for the SWP.

Implementation of Level I water management programs could reduce but not eliminate forecasted shortages in 2020 by implementing short-term drought management options (demand reduction through urban rationing programs or water transfers that reallocate existing supplies through use of reserve supplies and agricultural land fallowing programs) and long-term demand management and supply augmentation options (increased water conservation, agricultural land retirement, additional water recycling, benefits of a long-term Delta solution, more conjunctive use programs, and additional south-of-the-Delta storage facilities). Combined, these Level I programs

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Table 12-5. California Water Budget
(millions of acre-feet)

Water Demand/Supply	*1990* average	*1990* drought
Net Demand		
Urban—with 1990 level of conservation	6.8	7.1
—reductions due to long-term conservation measures (Level I)	0	0
Agricultural—with 1990 level of conservation	26.8	28.2
—reductions due to long-term conservation measures (Level I)	0	0
—land retirement in poor drainage areas of San Joaquin Valley (Level I)	—	—
Environmental	28.4	16.4
Other[1]	1.5	1.5
Subtotal	63.5	53.2
Proposed Additional Environmental Water Demands[2]		
Case I - Hypothetical 1 MAF	—	—
Case II - Hypothetical 2 MAF	—	—
Case III - Hypothetical 3 MAF	—	—
Total Net Demand	63.5	53.2
Case I	—	—
Case II	—	—
Case III	—	—
Water Supplies w/Existing Facilities Under D-1485 for Delta Supplies		
Developed Supplies		
Surface Water[3]	27.9	22.1
Ground Water	7.1	11.8
Ground Water Overdraft[3]	1.3	1.3
Subtotal	36.3	35.2
Dedicated Natural Flow	27.2	15.3
TOTAL Water Supplies	63.5	50.5
Demand/Supply Balance	0.0	-2.7
Case I	—	—
Case II	—	—
Case III	—	—
Level 1 Water Management Programs[4]		
Long-term Supply Augmentation		
Reclaimed	—	—
Local	—	—
Central Valley Project	—	—
State Water Project	—	—
Short-Term Drought Management		
Potential Demand Management	—	1.0
Drought Water Transfers	—	0.8
***Subtotal* - Level I Water Management Programs**	—	1.8
Net Ground Water or Surface Water Use Reduction Resulting from Level I Programs	—	0.0
NET TOTAL Demand Reduction/Supply Augmentation	0.0	1.8
Remaining Demand/Supply Balance Requiring Level II Options	0.0	-0.9
Case I	—	—
Case II	—	—
Case III	—	—

(1) Includes major conveyance facility losses, recreation uses, and energy production.
(2) Proposed Environmental Water Demands—Case I-III envelop potential and uncertain demands and have immediate and future consequences on supplies from the Delta, beginning with actions in 1992 and 1993 to protect winter run salmon and delta smelt (actions which could also protect other fish species).

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Table 12-5. California Water Budget
(millions of acre-feet)

2000 average	2000 drought	2010 average	2010 drought	2020 average	2020 drought
8.3	8.7	9.9	10.3	11.4	11.9
-0.4	-0.4	-0.7	-0.7	-0.9	-0.9
26.4	27.7	25.8	27.1	25.4	26.6
-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
28.8	16.8	28.8	16.8	28.8	16.8
1.5	1.4	1.5	1.4	1.5	1.4
64.3	53.9	64.9	54.5	65.7	55.3
1.0	1.0	1.0	1.0	1.0	1.0
2.0	2.0	2.0	2.0	2.0	2.0
3.0	3.0	3.0	3.0	3.0	3.0
—	—	—	—	—	—
65.3	54.9	65.9	55.5	66.7	56.3
66.3	55.9	66.9	56.5	67.7	57.3
67.3	56.9	67.9	57.5	68.7	58.3
27.8	21.5	28.1	21.6	28.2	21.7
7.1	12.0	7.2	12.1	7.4	12.2
—	—	—	—	—	—
34.9	33.5	35.3	33.7	35.6	33.9
27.4	15.4	27.4	15.4	27.4	15.4
62.3	48.9	62.7	49.1	63.0	49.3
—	—	—	—	—	—
-3.0	-6.0	-3.2	-6.4	-3.7	-7.0
-4.0	-7.0	-4.2	-7.4	-4.7	-8.0
-5.0	-8.0	-5.2	-8.4	-5.7	-9.0
0.5	0.5	0.6	0.6	0.8	0.8
0.0	0.1	0.0	0.3	0.0	0.3
0.0	0.0	0.0	0.0	0.0	0.0
0.2	0.1	0.6	1.0	0.7	1.0
—	1.0	—	1.0	—	1.0
—	0.8	—	0.8	—	0.8
0.7	2.5	1.3	3.8	1.5	3.9
0.1	0.0	0.1	0.2	0.1	0.2
0.7	2.5	1.4	4.0	1.6	4.1
—	—	—	—	—	—
-2.3	-3.5	-1.8	-2.4	-2.1	-2.9
-3.3	-4.5	-2.8	-3.4	-3.1	-3.9
-4.3	-5.5	-3.8	-4.4	-4.1	-4.9

(3) The degree future shortages are met by increased overdraft is unknown. Since overdraft is not sustainable, it is not included as a future supply.
(4) Protection of fish and wildlife and a long-term solution to complex Delta problems will determine the feasibility of several water supply augmentation proposals and their water supply benefits.

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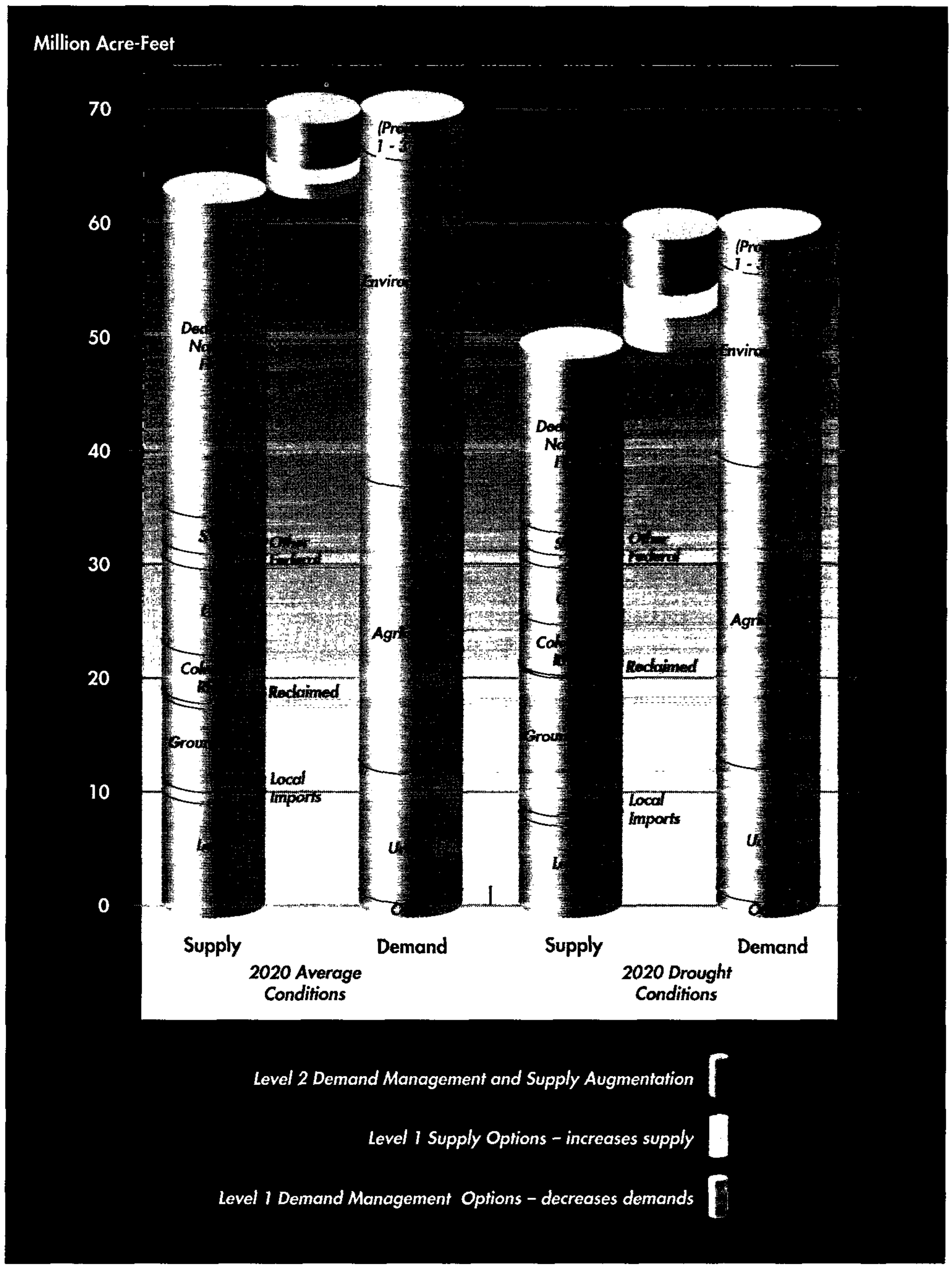
leave a potential shortfall in annual supplies of about 2.1 maf to 4.1 maf in average years and 2.9 maf to 4.9 maf in drought years by 2020. The shortfall must be made up by Level II water supply augmentation and demand management programs. (Chapter 11 explains these programs.)

The California Water Budget indicates the potential magnitude of water shortages that can be expected in average and drought years if no actions are taken to improve water supply reliability. Figure 12-1 illustrates the water supply benefits of short- and long-term water management programs under Level I options and the need for further investigating and implementing Level II options.

Figure 12-1. California Water Balance



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Recommendations

The Delta is the hub of California's water supply infrastructure; key problems in the Delta must be addressed before several of the Level I options in the California Water Plan Update can be carried out. It is recommended that finding solutions to those problems be the first priority. Also, a proactive approach to improving fishery conditions—such as better water temperature control for spawning, better screening of diversions in the river system to reduce incidental take, and better timing of reservoir releases to improve fishery habitat—must be taken so that solutions to the Delta problems mesh with basin-wide actions taken for improving fishery conditions. To that end, many of the restoration actions identified in the Central Valley Project Improvement Act for cost sharing with the State can improve conditions for aquatic species. Once a Delta solution is in place and measures for recovery of listed species have been initiated, many options requiring improved Delta export capability could become feasible.

Following are the major Level I options recommended for implementation to meet California's water supply needs to 2020, along with their potential benefits. Many of them still require additional environmental documentation and permitting, and in some instances, alternative analyses. Before these programs can be implemented, environmental water needs must be identified and prioritized and funding issues addressed.

Demand Management

- Water conservation—by 2020, implementation of urban BMPs could reduce annual urban applied water demand by 1.3 maf, and net water demand by 0.9 maf, after accounting for reuse. Implementation of agricultural EWMPs, which increase agricultural irrigation efficiencies, could reduce agricultural applied water demands by 1.7 maf and net water demand by 0.3 maf, after accounting for reuse. In addition, lining of the All-American Canal will reduce net water demand by 68,000 af.
- Land fallowing and water bank programs during droughts—temporary, compensated reductions of agricultural net water demands and purchases of surplus water supplies could reallocate at least 0.6 maf of drought-year supply. However, such transfers are impaired until solutions to Delta transfer problems are identified and implemented.
- Drought demand management—voluntary rationing averaging 10 percent statewide during drought could reduce annual drought-year urban applied and net water demand by 1.0 maf in 2020.
- Land retirement—retirement of 45,000 acres with poor subsurface drainage and disposal on the western San Joaquin Valley could reduce annual applied and net water demand by 0.13 maf by 2020.

Supply Augmentation

- Water reclamation—plans for an additional 1.2 maf of water recycling and ground water reclamation by 2020 could provide annual net water supplies of nearly 0.8 maf after accounting for reuse.
- Solutions to Delta water management problems—improved water service reliability and increased protection for aquatic species in the Delta could provide 0.2 to 0.4 maf annually of net water supplies (under D-1485) and make many other water management options feasible, including water transfers.

- Conjunctive use—more efficient use of major ground water basins through programs such as the Kern Water Bank could provide 0.4 maf of drought-year net water supplies (under D-1485).
- Additional storage facilities—projects such as Los Banos Grandes (SWP), could provide 0.3 maf of average and drought-year net water supplies (under D-1485), and Domenigoni Valley Reservoir (MWDSC) could provide 0.3 maf of drought-year net water supplies.

In the short-term, those areas of California relying on the Delta for all or a portion of their supplies face uncertain water supply reliability due to the unpredictable outcome of actions being undertaken to protect aquatic species and water quality. At the same time, California's water supply infrastructure is severely limited in its capacity to transfer marketed water through the Delta due to those same operating constraints. Until solutions to complex Delta problems are identified and put in place, and demand management and supply augmentation options are implemented, many Californians will experience more frequent and severe water supply shortages. For example, in 1993, an above-normal runoff year, environmental restrictions limited CVP deliveries to 50 percent of contracted supply for federal water service contractors in the area from Tracy to Kettleman City. Such limitations of surface water deliveries will exacerbate ground water overdraft in the San Joaquin River and Tulare Lake regions because ground water is used to replace much of the shortfall in surface water supplies. In addition, water transfers within these areas will become more common as farmers seek to minimize water supply impacts on their operations. In urban areas, water conservation and water recycling programs will be accelerated to help offset short-term reliability needs.

Finally, it is recommended that Level II options be evaluated, expanded to include other alternatives, and planned for meeting the potential range of average-year shortages of 2.1 to 4.1 maf and the potential range of drought-year shortages of 2.9 to 4.9 maf. Level II options include demand management and supply augmentation measures such as additional conservation, land retirement, increased water recycling and desalting, and surface water development. Several mixes of State and local Level II options should be examined, and their economic feasibility ascertained, to address the range of demand and supply uncertainty illustrated in the California Water Budget. Such uncertainty will affect the identification and selection of Level II options needed to meet California's future water supply needs.

Economic Costs of Unreliability

The economic cost of unreliability is significant and could impact the economic well-being of the State if nothing is done to improve the long-term reliability of supplies. For example, the economic cost of drought-induced water shortages in 1991 is estimated to have been well over $1 billion in business-related costs and losses; this does not include the large value of losses to residential users in terms of inconvenience, the aesthetic cost of putting up with stressed and dead landscaping during the drought, and the cost of replacing that landscaping after the drought. Substantial environmental damage was also experienced. This loss indicates an immediate need for more reliable supplies. The size of these losses is a strong indication that there are economically, socially, and environmentally justified water management options, including both demand management and supply augmentation, that should be implemented to increase reliability. This portion of Chapter 12 is presented to illustrate the economic costs of unreliability. Chapter 11 presented a discussion on reliability planning that guides the alternative analyses and option selection process. The following sections discuss contingency losses and long-term impacts resulting from frequent and severe shortages.

The most important element in analyzing the costs of unreliability is understanding the consequences of shortages as completely as possible in terms of where the costs occur and why. For this discussion, the costs of shortages are limited to short- and long-term contingency losses, loss of sales, and increased costs of production.

The costs discussed below do not include all possible costs of unreliable water supplies. The social costs of unreliability can be substantial, but they are not easily translated into consistently measurable units, such as dollars, and social impacts often result from the adverse effects of unreliability on economic welfare. Looking solely at economic value may not be completely satisfactory, but it is the most practical and rational method currently available. Two distinct consequences of unreliability incur economic costs: contingency losses and long-term losses. Contingency losses arise from failure to meet existing needs within any given year, whereas long-term losses stem from the perception that future shortages will be greater than what is considered tolerable.

Basically, these losses are caused by shortages, and shortages occur because of insufficient water quantity or unacceptable quality. Often these two factors combine, creating a shortage that is difficult to alleviate for the short- or long-term. For example, water supply conditions that limit the amount of water available for export from the Sacramento-San Joaquin Delta also make it difficult to maintain export water quality, as well as water quality for users within the Delta.

Areas that experience surface water shortages may be forced to turn to additional ground water pumping or rely on alternative surface water deliveries, both of which may result in higher costs or lower supply quality. Furthermore, increased reliance on ground water due to more frequent or more severe shortages can have long-term water quality consequences. (The adverse effects of reduced water quality are discussed in Chapter 5.)

Contingency Losses

The size and duration of a shortage will determine the contingency losses suffered. Some of the major costs incurred during water shortages are: loss of sales, loss of market share, costs of landscape replacement, damage to wildlife habitat, loss of recreational opportunities or aesthetic values, loss of convenience, and costs of short-

Water Service Reliability

Reliability is a measure of a water service system's expected success in avoiding detrimental economic, social, and environmental effects related to or caused by shortages. The long-term effects on economic activity (including business costs), environmental conditions, and social well-being, as well as shortage-related costs and losses, are important.

How reliable water service is for a particular agency depends on the size, frequency, and duration of shortages; the types of water use affected; the options available to the agency and water users for managing shortages; and the costs of contingency water management and losses associated with shortages. As water demand goes up over time due to expanding economic activity or a growing population, the size, frequency, and duration of shortages all increase, thus reducing reliability.

Long-term water management measures to increase supply or reduce demand can be put in place to reverse or slow the rate of this increase, but not without economic, social, and environmental costs. Also, additional contingency measures can be developed to better manage shortages and reduce their economic consequences when they occur, but such measures have their own costs.

In general, if the existing level of reliability is inadequate, taking action to increase it will cost less than not taking action, when all economic, social, and environmental costs and losses are considered for each alternative action. Conversely, if the existing level of reliability is adequate, taking action to increase reliability will cost more than not taking action when all economic, social, and environmental costs and losses are considered for each alternative action.

When examining the adequacy of the current level of reliability, the long-term consequences and shortage-related costs and losses must be identified by sector: agricultural, residential, commercial, and industrial. The secondary impacts of urban and agricultural shortages can also be substantial, a consideration that is particularly important with respect to the economic and social consequences of agricultural water service reliability.

Both the long-term and shortage-related impacts of unreliability are critically dependent on the shortage-management options available to local water managers. Contingency water transfers and emergency measures such as alternate-day landscape watering and gutter-flooder patrols can be effective in reducing the economic impacts of an urban shortage at a relatively minor cost. Beyond that, urban water allocation programs can compel users with the least to lose to absorb the major part of shortages. In agricultural areas, local intra- and interagency water exchange programs can be used to allocate surface water shortages to areas which overlie ground water and can substitute this latter supply to the extent that it is available and the farmers' finances permit. Agricultural shortages can also be allocated to areas with crops which are the least vulnerable in terms of foregone income or loss of investment if fields are fallowed, yields are reduced, or the crops are lost.

In urban areas, the desired shortage allocations to minimize overall economic impacts may be accomplished by specific allocations to different types of users, hardship exemption programs, punitive water pricing, or some combination of these strategies. The proper allocation varies with the size of the overall shortage and relative economic impact of each additional increment of shortage on the different sectors.

The relative impact of shortages depends on the slack users have at the time shortages occur (that is, how many low-cost actions can users take to manage shortages before serious consequences result) and the relative rapidity with which costs and losses escalate beyond the manageable point. In some cases, having put long-term measures in place can reduce the effectiveness of contingency measures when shortages occur. For example, reductions in applied water caused by better landscape management can mean that, in the

Water Service Reliability (continued)

future, emergency cutbacks may cause stress sooner, or may not be possible at all, because water use is already at maximum efficiency. Similarly, changes in technology for industrial process water used to increase efficiency may cause reduced production sooner for the same reasons.

In effect, the result of the urban rationing programs is to shift the worst impacts to residential exterior and commercial landscaping use and away from industrial use, commercial non-landscaping use, and residential interior use. Although this strategy is likely to reduce overall economic impacts, it can have serious impacts on businesses that depend on having water available for landscaping, such as golf courses, and on businesses dependent on establishing and maintaining residential landscaping. Also, to the extent that conservation is being practiced for residential exterior use and commercial landscaping use, this strategy will be less successful due to the lower level of waste or low-valued uses that are curtailed during shortages.

Two separate studies illustrate the comparative value of water use in industry and in residences. The average value foregone by California industries during a shortage of 30 percent was an estimated $74,000 per acre-foot (*Cost of Industrial Water Shortages*, California Urban Water Agencies, November 1991). The average value foregone by California residential water users during a shortage of 30 percent would produce a loss of about $2,600 per acre-foot (interpolated from the results in *Economic Value of Reliable Water Supplies*, State Water Contractors Exhibit 51, June 1987).

Because of the strategy of allocating shortages away from non-residential users to protect local income and employment, a 30-percent overall shortage can translate to somewhat greater than a 35-percent shortage for residential users, thus producing, for example, an equivalent loss of about $3,400 per acre-foot overall (assuming that the shortage allocation process has the effect of spreading the pain evenly among the different urban sectors). The actual loss after reallocation will depend on the relative amounts of the different types of water use and their relative vulnerability to economic loss.

In agricultural areas, the residential-user water shortage "buffer" available to cushion the impact on businesses in urban areas is usually not significant: employment impacts, business costs increases, and income losses can be more or less immediate. This is an important distinction in terms of the consequences for the health of the local economy, particularly in small agricultural communities where providing goods and services to farmers and hauling, storing, and processing farm products are the major activities.

As an example of the potential water shortage costs to farmers, costs associated with substituting ground water for unavailable surface water during 1991 resulted in added water costs in the San Joaquin Valley ranging from more than $20 per acre-foot of additional pumping to almost $60 per acre-foot, depending on the area affected. Farm income losses due to reduced acreage, or yield declines due to an overall shortage of about 6 percent to the San Joaquin Valley (after accounting for increased ground water pumping), ranged from about $45 to $1,100 per acre-foot, depending on the area affected (derived from *Economic Impacts of the 1991 California Drought on San Joaquin Valley Agriculture and Related Industries*, Northwest Economic Associates, March 1992).

Continuation of the recent drought, which would have had the effect of forcing ground water levels even lower and further straining the financial ability of farmers to substitute ground water for unavailable surface supplies, would have had more serious economic consequences than were experienced. The extent of the drought's impact on higher-investment crops such as truck, tree, and vine crops would likely have been greater. For example, income lost because vegetable crops were not planted due to water shortages would be about $470 per acre-foot of applied water. Farm income lost for citrus trees killed due to

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Water Service Reliability (continued)

water shortage would be $330 per acre–foot of applied water; this amount would be lost annually until the trees were replaced at a cost of about $10,500 per acre. The losses would then decline until the replacement trees reached full maturity in about ten years (derived from *Evaluation of the Economic Impacts of 1991 Drought Alternatives for Kern County Surface Water Districts*, Northwest Economic Associates, January 1991).

These examples of urban and agricultural impacts are related to the economic consequences of water shortages. The long–term economic consequences of unreliability are related to business decisions to make long–term investments in water use technologies (for example, emergency reuse systems) or alternative sources of supply (for example, wells) to better cope with shortages when they occur. Business decisions to locate in an area, move from an area, add or drop product lines, or expand or reduce overall production are also affected by water service reliability.

Long–term consequences of unreliability also show up in the value of land. Agricultural land in areas with more reliable supplies has a higher value than land in areas with less reliable supplies, all other factors being equal. Lower reliability can mean lower productivity because of higher losses caused by shortages. Unreliability can also limit the productivity of land by making farmers (or their lenders) unwilling to expose themselves to the higher degree of risk of investment loss when growing tree or vine crops, for example, although the soil and climate may be suitable and market conditions favorable.

In a similar fashion, property values for residential users and their quality of life may be lower in an area with less reliable water service if the expected cost of shortage–related landscaping replacement is high enough to discourage planting of preferred, high–investment landscaping. The secondary benefits to the local economy of expenditures on services needed to maintain high–investment landscaping can be another loss, if this type of landscaping is discouraged because of unreliable water supplies.

age management programs. Although not classifiable as regional economic losses, reduced water sales can place severe financial stress on water agencies with large fixed costs to meet.

Loss of Agricultural, Commercial, or Industrial Sales. Water is involved in the production of goods and services in a number of ways. Agricultural production probably has the most visible need for large amounts of water. Water also plays a vital role in industry where it is used for cooking, washing, cooling, and conveying as part of the processing, and water is often part of the product (for example, soft drinks).

In the short term, the production level can be independent of the amount of water available during a given year, depending on the flexibility of the manufacturer's water supply system. Emergency conservation and reuse measures can reduce the amount of water needed for some uses. The degree of flexibility available for managing shortages depends on the specific production technology used and the extent to which conservation and recycling measures already in place have reduced the opportunity for further conservation and reuse.

At a certain point, further water cuts will curtail business production and affect employment and sales. In some cases, the effects may extend beyond the shortage year. Farmers who stress trees due to water shortages may lose production not only during the shortage year, but also in future years, until the trees recover. Crop production can also be affected if shortages force farmers to substitute lower quality water for their normally available surface water. In the case of farms in the Sacramento–San

Joaquin Delta, increased salinity intrusion during water shortages reduces the quality of the irrigation water.

Water shortages indirectly affect businesses too. Housing construction can be delayed because of a shortage-related water connection moratorium. Drought perceptions or hearsay, as well as actual shortages, can hurt businesses catering to recreation. Landscaping businesses can be affected if customers choose to, or are forced to, let severely stressed landscaping die during shortages. Decreases in fish populations reduce income and employment in commercial fishing. Municipalities experiencing water shortages can lose revenues from public parks and golf courses. Water agencies can also experience loss of revenues due to reduced water sales during a drought.

Increased Costs for Agricultural, Commercial, or Industrial Users. The various ways businesses can avoid curtailing production may be effective but some can also be costly. Installing temporary recycling equipment is one example of a cost imposed by a water shortage. Reusing cooling water, while allowing continued production during a shortage, may result in costly mineral-scale removal to restore cooling efficiency later. Retrofit of water-saving equipment can be expensive, but it also has benefits beyond the immediate shortage, such as reducing the potential effect of future shortages during the life of the equipment and saving water and effluent charges. Lack of water for hydroelectric plants and reduced generating ability (as reservoirs are drawn down) forces electrical utilities to buy energy from other sources or expand the use of their thermal generation capacity. In either case, more costly operation is the result.

Farmers who have to substitute ground water to replace unavailable surface supplies incur increased costs during shortages. This substitution may require installing new wells or renovating existing ones, and in some cases the ground water is pumped from great depths, which adds to the expense. These ground water costs are in addition to the fixed costs agricultural water contract holders must pay for the surface water delivery system, whether or not any water has been delivered. Similarly, urban water agencies can be financially stressed by the obligation to meet large fixed delivery system costs with reduced water sales revenues, while being required to pay for costly supplemental supplies. A farmer can also institute more intensive (and more costly) irrigation management practices.

Cost of Landscaping Replacement. Replacing dead landscaping or invigorating stressed landscapes after a severe water shortage can be costly for municipalities, businesses, and homeowners. However, such expenses can help make up for income lost by seed and plant suppliers and landscape service businesses during a drought. Furthermore, while the landscaping is stressed, or until dead landscaping can be replaced, the cooling effect provided by healthy landscaping is reduced or lost. As a result, during summer months, city residents use air conditioners more often or for longer durations, and energy bills increase. Along with the replacement and additional cooling costs, there is also the loss of the aesthetic enjoyment provided by healthy grass, shrubs, and trees. Plant growth is also important for air quality because the plant transpiration process helps remove some pollutants from the air. It may be many years before replacement plants regain the stature (and the value) of trees and shrubs that were lost.

Loss of Recreational Opportunities. Water shortages reduce recreational opportunities in several ways. Reservoir, lake, and instream flow levels drop, causing water temperatures to rise and adversely affect fish. As water levels and fish populations decrease, so do opportunities for such activities as boating, camping, and fishing. The businesses serving these recreation industries and the people using recreational facilities suffer economic and other losses.

Loss of Convenience. Taking shorter showers or flushing the toilet less frequently in response to emergency water pricing, rationing, or voluntary conservation programs are inconveniences people would rather avoid. The ability to shower longer or flush toilets more frequently is worth something to most people.

The values of aesthetics and recreational opportunities, and of avoiding the loss of certain conveniences, are economic costs of water shortages. These costs can be measured by water users' responses to changes in water prices or by their responses to surveys. Although measurement is difficult with existing methods, research shows water for recreation, aesthetics, and convenience is of substantial value, especially during extended shortages.

Costs of Shortage Management Programs. Another cost of shortages is borne by water agencies that employ water shortage management techniques, such as public information campaigns, "water waster" patrols, retrofit programs, and water allocation programs. These added costs can be offset somewhat by lower variable costs (such as costs for energy) because reduced supply availability means less water to be treated and distributed by the agency. However, due to the nature and timing of shortages, funds and personnel shifts result in deferred maintenance and capital projects which increase long-term costs.

Long-Term Losses

Long-term losses are not related to a specific shortage event but are caused by unfavorable perceptions of the potential frequency and severity of future shortages. Some of the more damaging long-term losses are reduced economic activity, higher business costs, and constrained landscaping options.

Reduced Likelihood of Retaining or Acquiring Economic Activity in a Region. Many factors influence a company's decision to expand into a new area or move an existing plant. Examples include work force skills, prevailing wages, proximity to markets, energy costs, costs and quality of water supply, and costs of effluent disposal. Public service reliability is a factor when companies consider locating in an area because a better quality of life is more attractive to potential employees. Water service reliability to ensure uninterrupted production is another important factor. The expected costs of maintaining production during water shortages by using self-supplied water (if available), emergency conservation, or other shortage management measures are also important. If reliability cannot be assured and shortage management is costly or infeasible, a company may decide to locate elsewhere; if already located in an area with unreliable water supply, a company may decide to move. Either way, the jobs and income would be lost.

Business loans are likely to be more costly, and may be unavailable. Crop production loans for farmers are particularly vulnerable if business owners cannot assure lenders that their water supplies are reliable. Bonding agencies are generally reluctant to provide financing to a water agency with uncertain supplies that are interrupted during water shortages. The increased risk of shortage-related damage to costly perennial or truck crops will make farmers less willing to invest in these types of crops, endangering California's singular advantage in soils and climate for these high-valued crops. Agricultural markets for some crops are also sensitive to the buyers' perceptions regarding consistent product availability. Such markets can be lost if an unreliable water supply causes buyers to anticipate undependable product availability.

Higher Business Costs. For urban businesses facing unreliable water utility supplies, installing self-service capability, including arranging privately negotiated transfers (if feasible) or installing lower-use process and cooling water technologies, becomes an important cost consideration. For agricultural users overlying ground water, the need to increase reliability by installing increased ground water pumping capacity, to cope with anticipated surface water shortages, can be a major capital cost.

Environmental Costs of Unreliability

Environmental losses related to unnatural water supply variability can be serious, although not easily expressed in dollars. During critically dry years, wildlife habitat often diminishes, and plant and animal mortalities increase. This process occurs naturally, but can be exacerbated by water development that changes the natural flow patterns.

Wildlife Habitat. Shortage-related reductions in streamflow and increases in water temperature can have a devastating effect on fish spawning. Plants not killed outright by lack of moisture are made more susceptible to disease. In some instances, the impacts of drought on the environment can be reduced by water project operations. Projects can be used to either convey water or allow water transfers to environmentally sensitive areas that otherwise would not have sufficient water available.

Urban Wildlife Habitat. Urban trees, shrubs, and lawns, as well as parks and golf courses, provide habitat for birds and small mammals. Reduced runoff and shortages force irrigation cutbacks during drought which can lead to habitat loss in these areas.

Agricultural Wildlife Habitat. Irrigated cropland is a source of food for migrating waterfowl and other wildlife. Habitat provided by border areas and in crop stubble after harvest is also significant. Fallowing of this cropland can reduce food and habitat.

Economic Impacts of the Drought

The impacts of the 1987-92 California drought illustrate the consequences of shortages and the degree to which existing water management programs and projects have been successful in mitigating the drought's effects. Experiences from the recent drought and the 1976-77 drought have helped identify effective shortage management strategies.

Agricultural Impacts. DWR studies indicate that in 1990, the drought resulted in reduced gross revenues of about $220 million to California agriculture. This loss was attributed to reduced yields on about 75,000 drought-impacted acres and to lost output from about 194,000 drought-idled acres. Most of the State's drought-idled acres would have been planted in cotton and grains. However, much of the revenue loss resulted from reduced acres of high-value vegetable crops in the Central Coast Region. Commodities hit hardest in the drought were dry grains, dry hay, and beef cattle; agricultural areas suffering the most drought impacts were the west side of the southern San Joaquin Valley and the Central Coast Region.

The unusually abundant precipitation in March 1991 greatly helped Central Coast growers. It also benefited ranchers throughout California with improved range and pastureland. However, many farmers in the Central Valley and Southern California faced cuts in surface water deliveries of 15 to 100 percent. Estimated gross revenue loss to California farms was about $250 million in 1991 (the result of drought-idled acres of about 347,000 crop acres and reduced crop yields). Growers of barley, rice, wheat, and corn had the greatest relative declines in gross farm receipts. Again, growers on the west side of the San Joaquin Valley were hardest hit by the drought.

In 1992, California agriculture experienced an estimated gross revenue loss of about $190 million due to continuing drought, roughly $60 million less than the 1991 loss. The associated net amount of drought-idled farmland was about 279,000 acres. The decrease in idled acres was due largely to relatively abundant precipitation over most of the State during February and March. While growers along the Southern and Central coasts experienced the biggest improvements, farmers and ranchers in northeast California were generally worse off than before. Barley, cotton, and sugar beets were the hardest hit crops.

A record number of farm wells were drilled or deepened (about 1,700 in 1991 alone), substantially augmenting the ability to use ground water to replace curtailed surface water deliveries to farms. The continuing success of California's farm production is due, in large part, to the availability of ground water supplies. This success comes at a price, however. For example, in 1991, the cost to farmers for water increased over $160 million, primarily due to the higher cost of ground water use, causing financial hardship in the San Joaquin Valley (*Economic Impacts of the 1991 California Drought on San Joaquin Valley Agriculture and Related Industries*, Northwest Economic Associates, March 1992). The continued availability and affordability of increased ground water pumping as an agricultural drought management practice may be jeopardized in areas without replenishment from the percolation of rainfall or recharge from surface supplies.

A successful water bank and local water transfers helped assure normal yields on 113,000 acres of permanent crop land that had drought-impacted supplies in the San Joaquin Valley during 1991. Farmers made better use of local weather data, in conjunction with new irrigation technologies, to significantly reduce applied water in drought-impacted areas. Cropping patterns were changed to produce more revenue with less water. Growers in areas with adequate water increased their plantings to help offset drought-idled acres elsewhere in the State.

Municipal and Industrial Impacts. DWR surveyed over 60 urban water districts, chambers of commerce, trade groups, and industry associations throughout California regarding drought impacts to assess the effect of the 1987-92 drought upon the commercial and industrial sectors. Survey responses indicated that only one major industry group, the "green industry" (landscape and gardening industry), was significantly affected by the drought. Most firms were able to avoid significant reductions in output or employment in spite of overall water use cutbacks that reached or exceeded 20 percent in many major urban areas. This was partly due to agencies placing a proportionately higher reduction burden on residential customers.

Green industry firms, especially those in the coastal and mountain areas, were seriously impacted when customers deferred installing new landscapes and reduced maintenance of existing landscapes because of the drought. Public agencies that provide maintenance services to parks, schools, and highway landscaping were also adversely affected, as were public and private golf courses. The green industry lost about $460 million in gross revenues and 5,600 full-time jobs during 1991. Green industry firms contributed an estimated $7 billion toward the State's economy in 1990 and employed about 125,000 full-time workers. The industry may recover from the adverse effects of the drought with a likely short-term increase in business as customers replace drought-damaged landscapes or change landscapes to cope with future droughts.

One explanation for the minimal impact on most businesses is that most water agencies established exemption programs for hardship cases. In some instances, firms that otherwise would have been significantly affected were spared because their utilities granted them exemptions from water allocation limits. The rationale behind these exemptions for commercial and industrial utility customers was to keep job losses to a minimum. Some water agencies had water shortage allocation programs which called for residential customers to cut use to a greater extent than business users for this purpose, shifting shortage-related costs and losses to residential users. Another likely reason drought impacts were not as severe as might have been expected is that firms implemented additional conservation programs to compensate in part for lost supplies. There was also some additional flexibility to avoid business losses because of recession-related reductions in industrial production which lowered water demand by affected companies.

From a statewide perspective, the 1991 drought had a negligible effect on total urban water costs. However, some demand reductions could have been attributed to the recession. Additionally, at the local level, certain water purveyors experienced financial difficulties because they could not raise unit rates fast enough to offset their drought-induced revenue decline. The major drought impacts in urban areas has been the inconvenience and annoyance of lifestyle and comfort changes and the costs to residential water users in inconvenience and lost and damaged landscaping (with the accompanying loss of ambience and well-being), and delayed landscaping work.

Other Economic Impacts. Another economic impact of the drought arose from reduced hydroelectric generation capability. Energy utilities were forced to substitute more costly fossil-fuel generation at an estimated statewide cost of $500 million in 1991. The drought also adversely affected snow-related recreation businesses. Some studies suggest as much as an $85-million loss for snow-related recreation businesses during the winter of 1990-91.

Environmental Impacts. The impacts on the State's ecosystems were some of the most important and potentially negative aspects of the recent drought. Important environmental consequences of the drought are effects on freshwater, marine, and anadromous fisheries, wetland and marsh area reductions, and substantial forest damage from pests and fire. (Several of these consequences are discussed in Chapter 8, *Environmental Water Use.*)

Appendix A

A.1 Bibliography, Statutes, and Court Cases Cited in Chapter 2

Allocation and Management of California's Water Supplies

California Constitution Article X, Section 2

Riparian and Appropriative Rights

Attwater and Markle, "Overview of California Water Rights and Water Quality Law," 19 *Pacific Law Journal* 957 (1988), reprinted in the pocket part of *West's Annotated California Codes, Water Code Sections 1-6999* (1971).

Water Rights Permits and Licenses

Water Commission Act, Water Code Sections 1000 et seq.

See also Water Code Section 102.

Ground Water Management

AB 3030 (Stats. 1992, Ch. 947) repealed Water Code Sections 10750-10767, and adopted new Sections 10750-10755.4.

Public Trust Doctrine

National Audubon Society v. Superior Court of Alpine County, 33 Cal. 3d 419, 189 Cal. Rptr. 346 (1983), cert. denied, 464 U.S. 977 (1983).

United States v. State Water Resources Control Board, 182 Cal. App. 3d 82 (1986), sometimes called the Racanelli decision after Justice Racanelli who authored it.

Environmental Defense Fund v. East Bay Municipal Utility District, 20 Cal. 3d 327 (1977), vacated, 439 U.S. 811 (1978), opinion on remand 26 Cal. 3d 183 (1980).

Federal Power Act 16 U.S.C. Sections 791a-793, 796-818, 820-825.

Reclamation Act of 1902, 32 Stat. 388; 43 U.S.C. Section 391.

California v. United States, 438 U.S. 645 (1978).

California v. FERC, 110 S. Ct. 2024 (1990), sometimes called the Rock Creek decision.

First Iowa Hydroelectric Cooperative v. Federal Power Commission, 328 U.S. 152 (1946).

Sayles Hydro Association v. Maughan, 985F.2d 451 (1993).

Area of Origin Statutes

County of Origin Statutes (Water Code Sections 10505 and 10505.5) .

Area of Origin Protections (Water Code Sections 11128, 11460-11463).

Delta Protection Act (Water Code Sections 12200 - 12220).

Municipal Liability (Water Code Section 1245).

Water Code Section 1215 through 1220.

The Current Regulatory and Legislative Framework

Protection of Fish and Wildlife and Habitat

Endangered Species Act. 16 U.S.C. Section. 1531 et seq. (1973).

California Endangered Species Act. Fish and Game Code Section 2050 et seq. (1984).

Natural Community Conservation Planning Act. Fish and Game Code Section. 2800 et seq. (1991).

Dredge and Fill Permits

Section 404 of the Clean Water Act. 33 U.S.C. Section 1344.

Section 10 of the 1899 Rivers and Harbors Act (33 U.S. Section 403).

Releases of Water for Fish

Fish and Game Code Section 5937.

California Trout, Inc. v. the State Water Resources Control Board, 207 Cal. App.3d 585, 255 Cal. Rptr. 184 (1989).

Streambed Alteration Agreements

Fish and Game Code Sections 1601 and 1603 .

Migratory Bird Treaty Act. 16 U.S.C. Sections 703 et seq.

Environmental Review and Mitigation

National Environmental Policy Act. 42 U.S.C. Sections 4321 et seq. (1969).

California Environmental Quality Act. Pub. Res. Code Sections 21000 et seq. (1970).

Fish and Wildlife Coordination Act. 16 U.S.C. Sections 661 et seq.

Protection of Wild and Natural Areas

Wild and Scenic Rivers Act. (federal) 16 U.S.C. Sections 1271 et seq. (1968).

Wild and Scenic Rivers Act. (California) Public Resources Code, Sections 5093.50 et seq. (1972).

Wild Trout Streams

The Trout and Steelhead Conservation and Management Planning Act of 1979. Fish and Game Code Sections 1725–1728.

Fish and Game Code Section 703.

National Wilderness Act. 16 U.S.C. Sections 1131 et seq. (1964).

Water Quality Protection

The Porter–Cologne Water Quality Control Act Water Code Sections 13000–13999.16 (1969).

National Pollutant Discharge Elimination System 33 U.S.C. Sections 1341 and 1342 (Sections 401 and 402 of the Clean Water Act) (1972).

In 1972 the California Legislature passed a law amending the Porter–Cologne Act which gave California the ability to operate the NPDES permits program.

Drinking Water Quality

Safe Drinking Water Act (federal). 42 U.S.C. Sections 300f et seq.

Safe Drinking Water Act (California). California Health and Safety Code Sections 4010 et seq.

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Domestic Water Quality and Monitoring Regulations. Title 22, California Code of Regulations 64401 et seq.

California Safe Drinking Water Bond Law of 1976. Water Code Sections 13850 et seq.

California Safe Drinking Water Bond Law of 1984. Water Code Sections 13810 et seq.

California Safe Drinking Water Bond Law of 1986. Water Code Sections 13895 et seq.

California Safe Drinking Water Bond Law of 1988. Water Code Sections 14000 et seq.

San Francisco Bay and the Sacramento-San Joaquin Delta

The State Water Project and Federal Central Valley Project

The California Central Valley Project Act Water Code Section11100 et seq.

Specific laws authorizing construction of elements of both the State and federal projects are summarized in *A.3 Acts Authorizing the State Water Project and Central Valley Project*.

Decision 1485, State Water Resources Control Board April 29, 1976.

The Racanelli Decision *United States v. State Water Resources Control Board*, 182 (Decided August 1978) Cal. App. 3d 82 (1986).

Coordinated Operation Agreement

Congress enacted legislation authorizing execution of the agreement in October 1986. P.L. 99-546; 100 Stat. 3050.

Fish Protection Agreement

Department of Water Resources and Department of Fish and Game, December 1986.

Suisun Marsh Preservation Agreement

The Suisun Marsh Preservation and Restoration Act of 1979 authorized the Secretary of the Interior to enter into a Suisun Marsh cooperative agreement with State of California and specified the federal share of costs of facilities. P.L. 96-495; 94 Stat. 2581.

Surface Water Management

Regional Water Projects

For a summary of the major regional projects, see Section A.2, *Acts Authorizing Regional and Local Water Projects.*

DWR Bulletin No. 155-77: *General Comparison of Water District Acts* (May 1978), which is being revised and should be republished in 1994, contains a full listing of water district acts. For a summary of some of the major acts that include a large number of districts, see Section A.2, *Acts Authorizing Regional and Local Water Projects.*

The Central Valley Project Improvement Act of 1992 P.L. 102-575; 106 Stat.4706.

Trends in Water Resource Management

Water Transfers

See generally Water Code Sections 1706 and 1725-1746.

In 1991, temporary changes to the law designed to facilitate the State Drought Water Bank were enacted. Stats. 1991-92, 1st Ex. Section, c. 3.

The Central Valley Project Improvement Act of 1992, P.L. 102-575; 106 Stat. 4706.

These changes were made permanent in 1992. Stats. 1992, c.481; Water Code Sections 1745-1745.11.

Water Use Efficiency

Article X, Section 2 of the California Constitution.

Water Code Section 275.

Imperial Irrigation District v. State Water Resources Control Board, 225 Cal. App.3d 548, 275 Cal. Rptr. 250 (1990).

Urban Water Management Planning Act. Water Code Section 10610 et seq. (1983).

The Water Conservation in Landscaping Act. Government Code, Section 65591 et seq.

The model ordinance was adopted in August 1992, and has been codified in Title 23 of the California Code of Regulations (§ 490–492).

Agricultural Water Management Planning Act. Water Code, Section 10800 et seq. (1986) .

Agricultural Water Suppliers Efficient Water Management Practices Act. Water Code, Section 10900 et seq. (1990).

Agricultural Water Conservation and Management Act of 1992. Water Code, Section 10521 et seq.

Urban Best Management Practices MOU.

Water Recycling Act of 1991. Water Code Section 13575 et seq.

Management Programs

Sacramento River Fishery and Riparian Habitat Restoration (SB 1086). SB 1086, passed in 1986, Senate Concurrent Resolution No. 62 (passed 1989).

The San Joaquin Valley Drainage Program.

San Joaquin Valley Drainage Relief Act (Water Code Sections 14900–14920, Stats. 1992, c. 959).

The Central Valley Project Improvement Act of 1992, P.L. 102–575; 106 Stat. 4706.

San Joaquin River Management Program. Water Code Sections 12260 et seq. (1990). Stats. 1990, Ch. 1068.

Interstate Water Resource Management

Truckee–Carson–Pyramid Lake Water Rights Settlement Act of 1991 Title II of P.L.101–618; 104 Stat. 3289 (1990).

See Water Code Section 5976.

For further information on the history of the Truckee River water rights disputes, and how they are addressed by the Settlement Act, see DWR's June 1991 *Truckee River Atlas*, and the December 1991 *Carson River Atlas*.

A.2 Acts Authorizing Regional and Local Water Projects

Hetch Hetchy Project. Raker Act (Act of December 6, 1913; 38 Stat. 242) The Hetch-Hetchy Project, which supplies water to the City of San Francisco and 33 Bay Area communities, includes two reservoirs within Yosemite National Park (Hetch-Hetchy Reservoir and Lake Eleanor) and three within Stanislaus National Forest (Lake Lloyd Project and Moccasin Reservoir). In the Raker Act, Congress granted the city rights-of-way within the Park and Stanislaus National Forest to construct these facilities. Federal law has been modified recently to prohibit new reservoirs or expansion of existing reservoirs within National Parks.

Colorado River Aqueduct. Metropolitan Water District Act (Stats. 1927, Chapter 429, *repealed and reenacted* Stats. 1969 Chapter 209, *as amended*; Cal. Water Code Appendix Sections 109-1 et seq.) The Colorado River Aqueduct supplies water from the Colorado River to serve several major urban areas in southern California. The Metropolitan Water District Act of 1927 allowed these areas to form the Metropolitan Water District of Southern California. Under the act, the district was granted the authority to acquire water and water rights within and without the state. It also gave the district the power to acquire real property through purchase, lease or eminent domain, and the power to acquire, construct, operate, and maintain all works, facilities, and improvements necessary to provide water to inhabitants of the district. The district also was granted the power to issue and sell bonds, levy and collect general taxes, employ laborers, and enter into contracts.

Los Angeles Aqueduct. The authority for the Los Angeles Aqueduct appears to come solely from Article 11, Section 19 of the California constitution, which authorizes municipal corporations to establish and operate public works for supplying their inhabitants with water, and from the City of Los Angeles charter. In 1905 Los Angeles voters approved a bond for the purchase of the original rights-of-way for the aqueduct from Owens Valley, with President Roosevelt allowing rights-of-way over federal lands in 1908.

Mokelumne River Aqueduct. The Municipal Utility District Act of 1927, Stats. 1921, c. 218 as amended; Public Utility Code Section 11501 et seq. This act grants the East Bay Municipal Utilities District the power to acquire, construct, own, operate, control, or use, within or without the district, works for supplying inhabitants of the district with water and other utilities. The act also grants the district the powers of eminent domain, taxing, and issuing and selling bonds. The Mokelumne River Aqueduct began transporting Sierra water to East Bay cities in 1929.

Regional and Local Water Distribution. There are over 40 different statutes under which local agencies may be organized, having among their powers the authority to distribute water. In addition, there are a number of special act districts. DWR Bulletin No. 155-77: *General Comparison of Water District Acts* (May 1978), which is currently being revised and should be republished in 1993, contains a full listing of these statutes. A summary of some of the major acts which include a large number of districts follows:

County Water Districts. Water Code, Div. 12, Sections 30000-33901 (1913). The County Water District Law authorizes the people of a county, or two or more contiguous counties, or a portion of a county or counties, to form a county water district. A district may do whatever is necessary to furnish sufficient water in the district for any present or future beneficial use, including: acquiring, appropriating, controlling, conserving, storing, and supplying water; draining and reclaiming lands; generating and selling incidental hydroelectric power; using any land or water under district control for recreational purposes; acquiring, constructing, and operating sewer, fire protection, and sanitation facilities.

Irrigation Districts. Water Code, Div. 11, Sections 20500-29978 (1897). Under Irrigation District law, a majority of the owners of land susceptible of irrigation from a common source, or 500 or more petitioners residing in the proposed district or owning at least 20 percent in value of the land therein, may propose the formation of an irrigation district. A district may do whatever is necessary to furnish sufficient water in the district for any beneficial use. These powers include controlling, distributing, salvaging, and other acts, any water, including sewage, for beneficial use, to provide drainage, or develop and distribute electric power. The district has the power to allocate water according to crops and acreage in certain situations, provide flood control in districts of 200,000 acres or more, provide sewage disposal upon approval of voters by majority vote, and construct and operate incidental recreational facilities.

Municipal Utility Districts. Public Utilities Code, Div. 6, Sections11501-14401. Under the Municipal Utility District Act, any "public agency" (city, county water district, county sanitation district, or sanitary district) together with unincorporated territory, or two or more public agencies with or without unincorporated territory, may organize and incorporate as a municipal utility district. These agencies may be in the same separate counties and need not be contiguous; however, no public agency shall be divided. A district may do all things necessary to acquire, construct, own, operate, control, or use works for supplying inhabitants of the district with light, water, power, heat, transportation, telephone service, or other means of communication, or means for the collection, treatment, or disposition of garbage, sewage or refuse matter; and provide for waste water control, including sewage and industrial wastes.

Municipal Water Districts. Water Code, Div. 20, Sections 71000–73001. Under the Municipal Water District Law of 1911, the people of any county or counties, or of any portions thereof, whether or not such portions include unincorporated territory, may organize a municipal water district. The lands need not be contiguous. A district may acquire, control, distribute, store, spread, sink, treat, purify, reclaim, recapture, and salvage any water, including sewage and storm waters, for beneficial uses of the district, its inhabitants, or owners of rights to water in the district; sell water to cities, public agencies and persons, in the district only, unless there is a surplus; construct and operate recreational facilities appurtenant to district reservoirs; collect, treat, and dispose of sewage, waste, and storm water; provide fire protection, first aid, ambulance and paramedic service; collect and dispose of garbage, waste, and trash; and produce and sell hydroelectric power.

Public Utility Districts. Public Utilities Code, Div. 7, Sections 11501–18055. Under the Public Utility District Act, the people of unincorporated territory may organize a public utility district. The district may do whatever is necessary to acquire and operate, within or without the district, works for supplying inhabitants with light, water, power, heat, transportation, telephone or other means of communication, means for disposition of garbage, sewage, or refuse matter; purchase and distribute such services and commodities; acquire and operate a fire department, street lighting system, public parks, playgrounds, golf courses, swimming pools, recreation and other public buildings, and drainage works.

Water Conservation Districts. Water Code, Div. 21, Sections 74000–76501. The Water Conservation Act of 1931 was declared to be a continuation and re-enactment of the Water Conservation Act of 1929, and also covers districts organized under the Conservation Act of California (Stats. 1919, c. 332). The board of supervisors of any county may organize and establish a district; or qualified electors in an area comprising the whole or a part of one or more watersheds may petition for organization and establishment of a district. The district may be entirely or partly within unincorporated territory, may be within one or more counties, and need not be contiguous. A district may do all acts necessary for the full exercise of its powers, which include: conserving and storing water by dams, reservoirs, ditches, spreading basins, sinking wells, sinking basins, etc.; appropriate, acquire, and conserve water and water rights for any useful purposes; obtain water from wells; sell, deliver, distribute, or otherwise dispose of water; make surveys; provide recreational facilities; provide flood protection; and reclaim sewage and storm waters.

A.3 Acts Authorizing Elements of the State Water Project and the Central Valley Project

The State Water Project

The California Central Valley Project Act. Water Code Section 11100 et seq. Approved by the voters in a referendum in 1933, this act authorized construction of the Central Valley Project. The State was unable to construct the project at that time because of the Great Depression, and portions of it were subsequently authorized and constructed by the United States (see below). Other portions of it were constructed by the State after the Depression as part of the State Water project, which includes: the Feather River Project (§11260), the North Bay Aqueduct (§11270) and various power facilities (§11295). The act permits the Department to administratively add units to the project, so long as those units are consistent with the objectives of the project (§ 11290). The Department is authorized to issue Revenue bonds to finance the project (Sections 11700 et seq.).

The Burns-Porter Act. Water Code Section 11930 et seq. The act was adopted in 1959 and approved by the voters in 1960. It authorized the issuance of general obligation bonds in the amount of $1,750,000,000 and appropriated the California Water Fund for the State Water Resources Development System, commonly known as the State Water Project (SWP). Principal facilities include Oroville and San Luis Dams, Delta Facilities, the California Aqueduct, and North and South Bay Aqueducts. The provisions of the California CVP Act are incorporated into the Burns-Porter Act.

The Central Valley Project

Reclamation Act of 1902. 32 Stat. 388; 43 U.S.C. Section 391. This act created the predecessor to the Bureau of Reclamation and provided the framework for development of water in the Western states through federal reclamation projects. It established a revolving fund from the sale of public lands to finance location and construction of irrigation projects (which are now constructed with general funds), and provided for the repayment of project costs through contracts with users. It contained acreage limitations and residency requirements for the farmers using the irrigation water. Section 8 of the act contains a "savings clause," deferring to state laws relating to the control, appropriation, use, or distribution of water for irrigation. (For more discussion of the savings clause, see the *Federal Power Act* section in Chapter 2.)

The Rivers and Harbors Act of 1937. Authorizes construction of Shasta, Friant, Keswick, DMC, Coleman Hatchery, etc., subject reclamation laws. P.L. 75-392; 50 Stat. 884. As amended by the Rivers and Harbor Act of 1940, P.L. 76-868; 54 Stat. 1198 (added irrigation and distribution systems).

Reclamation Project Act of 1939. P.L. 75-260; 53 Stat. 1187. This act provided for a 40-year term for repayment of contracts, and included provisions for payment and accounting.

San Luis Unit Authorization Act. San Luis Dam and pump-generation, O'Neil Forebay, San Luis Canal, Pleasant Valley Canal (Coalinga Canal); provisions for assurances from State for joint use facilities, including master drain; no water for production of excess agricultural commodities; USBR may turn O&M over to State. P.L. 86-488; 74 Stat. 220.

Flood Control Act of 1962. New Melones, Hidden, and Buchanan dams; includes fish and wildlife measures, recreation; electric power to preference customers. P.L. 87-874; 76 Stat. 1173.

Reclamation Project Act Amendments of 1956. P.L. 84-643; 70 Stat. 484; 43 U.S.C. Section 485h-5; P.L. 88-44; 77 Stat. 68; 43 U.S.C. Section 485h. Contract terms and conditions were changed to provide that long-term contractors have first right to stated amount of water on renewal. It also permitted M&I long-term contracts to include a renewal provision, including first right to a stated amount of water.

Auburn-Folsom South Unit Authorization Act. Auburn Dam and Powerplant, Sugar Pine Reservoir, Folsom-South Canal, recreation and fish and wildlife enhancement facilities; Secretary recommend to Congress compliance with state laws, including areas of origin. P.L. 89-161; 79 Stat. 615; 43 U.S.C. Section 616b et seq.

San Felipe Division Authorization Act. Pacheco Tunnel, pumping plants; recreation and fish and wildlife in accordance with Fed. Water Project Recreation Act; contracts with SWP; Excess land limitations not applicable; surplus crops limitation. P.L. 90-72; 81 Stat. 173.

Trinity River Stream Rectification Act. Authorizes Secretary to design and carry out sand dredging operation on Trinity River near Grass Valley Creek and a debris dam on that Creek;

matching funds from the State of California; all costs are nonreimbursable. P.L.96-355; 94 Stat. 1062.

Suisun Marsh Preservation and Restoration Act of 1979. Authorizes Secretary to enter into Suisun Marsh cooperative agreements with State of California for mitigation of adverse effects of CVP on fish and wildlife resources of Suisun Marsh; specifies Federal share of costs of facilities. P.L. 96-495; 94 Stat 2581.

Reclamation Reform Act of 1982. P.L. 97-293; 96 Stat. 1263; 43 U.S.C. Section 390 aa et seq. This act revises the acreage limitation of the 1902 act from 160 acres to 960 acres and eliminates the residency requirement if a district amends its existing contract to conform to the 1982 act. Districts not electing to amend their contract remain subject to prior law, except that water may be delivered to their land holdings in excess of 160 acres only at full cost (the "hammer clause"). Deliveries to holdings in excess of 960 acres are also authorized, but only if such excess lands are subject to a recordable contract requiring disposal of the excess lands within a reasonable time.

Trinity River Basin Fish and Wildlife Management Act. Directs the Secretary to formulate and implement a fish and wildlife restoration program designed to restore fish and wildlife populations to levels which existed before construction of Trinity River Division facilities; directs Secretary to enter into MOU with state, local agencies, and Native American tribes to implement activities not in Secretary's jurisdiction; establishes Trinity River Basin Fish and Wildlife task force. P.L. 98-541; 97 Stat. 2721 (1984).

Central Valley Project Improvement Act. Title XXXIV of P.L. 102-575 (1992). This act reauthorizes the CVP to include fish and wildlife among Project purposes, and directs the Secretary of the Interior to undertake a number of specified actions to protect and restore anadromous fish and wildlife habitat, and to dedicate specified amounts of water for that purpose. The act prohibits new CVP water supply contracts until the specified fish and wildlife restoration activities are carried out and the SWRCB completes the review of Delta water quality studies required by the *Racanelli* decision (see Bay-Delta section of text). The Secretary must prepare a programmatic environmental impact statement on the impacts of fish and wildlife restoration and renewal of existing water supply contracts. Until that EIS is done, existing contracts can be renewed for an initial interim period of three years and subsequent interim periods of two years. Thereafter, the Secretary must renew contracts for a 25-year period, and may renew contracts for subsequent 25-year periods. The act also authorizes marketing of CVP water outside the CVP area (see Water Transfer section below), subject to a first right of refusal within the CVP and other specified criteria, and it requires the Secretary to develop water conservation standards for the CVP.

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A.4 Several Acts Regulating Activities Affecting the Environment

Following is a summary of environmental statutes not covered in Chapter 2.

Federal

National Historic Preservation Act. 16 U.S.C. Section 470 et seq. This act directs Secretary of the Interior to expand and maintain a National Register of Historic places and establishes criteria for state historic preservation programs. It provides for grants and loans for the preservation of eligible properties and requires federal agencies to take into account the effect of a proposed federal undertaking or assistance on sites, buildings, or objects included or eligible for inclusion in the National Register. It also establishes a number of specific responsibilities for Federal agencies to assume for historic properties which they own or control.

Archaeological Resources Protection Act of 1979. P.L. 96-95; 93 Stat. 721; 16 U.S.C. Section 470 aa et seq. This act requires a Federal permit to disturb or remove any archaeological resource from specified federal lands, including national forests and wildlife refuges, and lands included in a National Park or under the jurisdiction of the Smithsonian Institution.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980. P.L. 96-510; 94 Stat. 2772; 26 U.S.C. Section 4611 et seq; 42 U.S.C. Section 9601 et seq. This act confers broad authority on the EPA to clean up or order the cleanup of hazardous substance contamination through removal or remedial actions and establishes liability for potentially responsible parties (PRPs) to either carry out or fund cleanup actions. It sets up a National Priority List of the most seriously contaminated sites and creates a "Superfund" to help finance cleanups. The EPA may order PRPs or seek court orders compelling PRP's to undertake response actions to abate threats to heath, public welfare, or the environment. The act provides civil and criminal penalties for violations.

Resource Conservation and Recovery Act. 42 U.S.C. Section 6901 et seq. This act regulates the generation, transportation, treatment, storage, and disposal of hazardous waste through a "cradle to grave" record-keeping process and includes a corrective-action program to clean up spills and releases.

State

Hazardous Waste Control Law. Cal. Health & Safety Code Section 25300 et seq. Regulates hazardous waste from time of generation to final disposal and governs State program pursuant to the federal RCRA.

Underground Storage Tank Act. Cal. Health & Safety Code Section 25280 et seq. Regulates construction, permitting, and monitoring of underground storage tanks in lieu of provisions under the federal RCRA.

Toxic Pits Cleanup Act. Cal. Health & Safety Code Section 25208 et seq. Regulates surface impoundments of liquid hazardous wastes to protect drinking water supplies.

Hazardous Substance Account Act. Health & Safety Code Section 25300 et seq. Authorizes State to oversee cleanups of hazardous contamination and establishes a fund to assist in paying cleanup costs.

Petroleum Underground Storage Tank Cleanup Act. Health & Safety Code Section 25299.10 et seq. Establishes fund for cleanups of leaking underground petroleum tanks and governs State program pursuant to federal RCRA provisions pertaining to underground petroleum tanks.

Appendix B

Public Comments on the Draft California Water Plan Update

Background

While developing *The California Water Plan Update*, Bulletin 160-93, the Department of Water Resources actively sought the public's involvement. An outreach advisory committee of representatives from urban, agricultural, and environmental interests was established in July 1992 to guide the Department of Water Resources in preparing the plan. The committee met regularly to comment on the work in progress. In addition, the California Water Commission held hearings in each of the State's ten hydrologic regions during January and early February 1994 to receive comments about the November 1993 draft update. After considering comments received from over one hundred individuals who attended the hearings, the Commission developed several recommendations. These recommendations provided added policy guidance for the final water plan update and are shown in the following copy of the April 1, 1994, memorandum from the Commission to the Department.

This appendix summarizes comments received from December 1993 through mid-February 1994. It is the result of sifting through over a thousand pages of documents acquired at the hearings and throughout the comment period. While most commentators complimented the Department on the breadth and quality of the report, concerns and issues were raised and are summarized here.

The majority of the comments revealed groupings of concerns that were commonly repeated but worded in varying ways; these are abridged below. Summaries of comments addressing the draft plan in its entirety are under *The Plan as a Whole*; the rest are ordered according to the parts of Bulletin 160-93. Comments that were uncommon are in the *Miscellaneous* section of this appendix. At the end of each summary are the sections or chapters in the bulletin that address the subject of the comment. Specific comments about wording or suggested technical changes and corrections were considered and included, where appropriate, in the final plan; however, these comments are not reproduced here due to space limitations. Copies of all the written comments received are available for readers to review at any of the Department's district offices. (See the end of this appendix for their addresses.)

Report of the California Water Commission: Hearings on the Draft California Water Plan Update

State of California — The Resources Agency

Memorandum

Date : April 1, 1994

To : David N. Kennedy
Director

From : **CALIFORNIA WATER COMMISSION**

Subject : Report of the California Water Commission on Hearings Held on the November, 1993 Draft of the California Water Plan Update

Members of the California Water Commission conducted ten hearings on the Department of Water Resources draft of Bulletin 160-93, California Water Plan Update ("Draft"). These hearings were held in January and early February of this year in each of the State's ten major hydrologic regions. This memorandum summarizes some of the major issues raised at the hearings, and it sets forth the Commission's comments and observations. Specific recommendations are shown in *italics*.

1. Advisory Committee. The Commission believes that the efforts of the Bulletin 160 Advisory Committee members contributed to the overall breadth and quality of the Draft. *The Commission recommends that the Department consider convening a similar committee on a continuing basis to assist in the preparation of updates to Bulletin 160 and more frequent periodic updates of the water balance studies. The Commission also recommends that the Department consider utilizing the assistance of such a committee in the development of an appropriate action plan, to meet future needs, including facilitating the development of local plans.*

2. Fixing the Delta. A majority of the witnesses concurs that the current impasse concerning Sacramento-San Joaquin Delta issues must be resolved. The Commission recognizes that achieving and maintaining a viable ecosystem in the Bay-Delta Estuary is an essential near-future and long-term objective of California's water policy. Achieving reasonable consensus among all interests concerned about the Delta is essential to California's environment and its economy. It must be made to work for both water users and the environment, or it will not work well for either. Some witnesses pointed out that fixing the Delta will be very expensive. While this may be true, the Commission believes that, regardless of cost, we must achieve a Delta fix to maintain the State's economy and meet the needs of its people and its environment.

   - *The Commission recommends that an ecosystem approach be taken in developing a solution to the problems of the Bay-Delta estuary.* Due consideration needs to be given to the impacts of water projects, but not to the exclusion of other significant factors which contribute to the problems of the Delta, including the proliferation of harmful non-native species, water quality. impacts on riverine habitat and wetlands and local and worldwide fishing pressure, both legal and illegal.

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- Achieving reasonable consensus on a long-term solution to the problems of the Delta will require close cooperation among a number of State and Federal agencies, as well as water users, fishery interests and other affected parties. *The Commission supports the approach taken by the Governor's Bay-Delta Oversight Council and it concurs with others in recognizing that the process should be broadened to include participation by Federal agencies.*

- Several speakers made the point that some Delta resources, such as its fisheries and recreational benefits are of value to the entire State and should be funded from State general funds (eg. general obligation bonds) rather than exclusively from the water users. The Commission believes that this issue should be considered and debated at an early date. It should be stressed that this issue transcends the completion of Bulletin 160 - 93; and the Commission is not recommending that the Bulletin address this issue, per se. *The Commission recommends that, as a part of achieving reasonable consensus, serious study and debate be given to determine which California interests are beneficiaries of specific Delta resources and accordingly, which interests should contribute to the costs of rectifying current problems of the Bay-Delta estuary.*

- The Draft properly recognizes that water transfers will form a part of the State's system for allocating Level I future water supplies, obtaining a reasonable amount of water from voluntary transfers depends on achieving a Delta fix. Meeting present and future contractual commitments and water needs from the Federal Central Valley Project and the State Water Project also require a completely viable Delta ecosystem. *The Commission recommends that projections of future water transfers include, where appropriate, a corresponding reference to the need for a Delta fix, which is imperative to the success of water transfers on any significant scale.*

3. <u>Urgency of current shortages and the need for future supplies</u>. Most witnesses stated and the Commission concurs that the Draft does not adequately describe the shortfall between available supplies and water needs, both now and in the near future. They noted that the general tone of the Draft does not fully convey the urgency of present and near-term water needs.

- The Draft applies 1990 water supply conditions which have been subsequently impacted by Delta criteria imposed by the administration of the Endangered Species Act and proposed administration of the Clean Water Act. This is understandable, because the most recent changes proposed for Federal criteria occurred on December 15 1993, after the Draft was released. The Commission recognizes that the Environmental Protection Agency's proposed water quality

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standards are not now in effect and may be modified. It also needs to be recognized that the method of implementing any such standards is uncertain. Accordingly, the Commission is not recommending that Bulletin 160 speculate on the specific impacts of the proposed standards or the quantities of water involved since the impacts probably would occur within the Draft's demand/supply water balance range of 1 to 3 million acre feet (see Table 12-6). Nonetheless, the Bulletin should recognize in some appropriate manner that the proposed standards, Endangered Species Act requirements and other administrative actions have reduced supplies available in recent years and have the potential for further significant reductions in the availability of water for consumptive uses. *Subject to the above considerations, the Commission recommends that the Draft consider the potential impacts of the Environmental Protection Agency's proposed December 15 Clean Water Act criteria, current administration of the Endangered Species Act by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, as well as other criteria imposed by the State Water Resources Control Board and other administrative agencies.*

- *The Commission recommends that the Department prepare periodic updates of the water balance studies, comparing the availability of water supplies with water needs, whenever there are significant changes in potentially applicable operational criteria affecting the major water projects.*

4. Economic issues. Many speakers pointed out that water shortages adversely affect California's economy, and they argued that the Draft did not provide sufficient economic analysis of the impacts of urban, agricultural and environmental water shortages.

- The Commission recognizes that performing detailed economic studies would unreasonably delay the completion of Bulletin 160-93. Nonetheless, the Plan could further highlight that water shortages have adverse economic effects. *The Commission recommends that the Plan include a recommendation for additional future funding for the Department to provide economic analysis for future updates. This should include analysis of the costs required for Level II options which could reduce anticipated water shortages.*

5. Environmental Water Needs. A number of speakers specifically complimented the Department for including environmental water needs as a part of the statewide water use data. The Commission supports the inclusion of these data.

- *To the extent practicable, the Commission recommends that environmental water use data be included in Bulletin 160-93 and that they be separated into sub-categories, such as wild and scenic rivers, fisheries and wetlands.*

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- A number of speakers noted that most needs of water for most consumptive uses and non-consumptive uses, such as hydroelectric power and recreation, can be specifically quantified; however, the needs of water to sustain fisheries and endangered species have not been satisfactorily quantified. There is a substantial lack of good scientific bases to support the quantities asserted to be desirable by some fishery interests. The Commission believes that there is a serious need to address this issue and to encourage research and dialogue among Federal and State agencies, as well as private research groups, water users, fishery interests and other interested parties. *The Commission believes that the Bulletin should note the need to quantify environmental water needs, particularly fisheries, based upon sound science.*

6. Urban and domestic water use issues.
   - A number of speakers urged that water rationing for drought demand management be treated as a Level II option rather than Level I. *The Commission concurs with the Department's treatment of voluntary rationing as a Level I issue, but the Bulletin should emphasize that the choice of demand reduction measures, as well as their magnitude and timing, is a decision which each water supplier should make, based upon its water conservation plan, supply availability and other relevant factors.*

   - Some speakers stated that the Plan should analyze the impact of the new Federal drinking water regulations. The Commission believes that this very significant issue is beyond the scope of Bulletin 160, and need not be analyzed in finalizing the Bulletin.

   - Some speakers pointed out that the mountain counties face unique water supply problems due to rapid residential growth and limited surface and ground water supplies. *The Department should consider appropriate additions to Volume II of the Draft (Regional Issues) to identify the problems faced by the mountain counties in meeting their present and future needs.*

7. Agricultural water use issues.
   - Speakers representing agricultural interests pointed out that the Draft should include recognition that a growing population in California and elsewhere will require a substantial increase in food supply, whether it is grown in California or elsewhere. The Commission recognizes that the issue of food supply involves a number of complex State and Federal policies, both domestic and international, which are beyond the scope of Bulletin 160. However, the inclusion of this point would serve to remind policy planners of the relationship of food production to

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the State's economy. *The Commission recommends that Bulletin 160-93 include an appropriate discussion which addresses the issues of meeting food supply needs, which should be considered in setting future policy, and that the demand for developed water for agricultural use may need to be reconsidered when the State develops this policy as to how this need will be met.*

8. Water Transfers.
   - Several speakers stated that the Draft does not include an adequate identification of potential future water transfers, both short-term and long-term. The Commission believes that water transfers are an important part of the allocation of the State's water supply. However, transfers should be voluntary, undertaken between willing buyers and sellers. In addition, careful attention needs to be paid to the potential impacts of a transfer on other lawful users of water, on fish and wildlife, and on the overall economy and environment of the area from which the water would be transferred. Every proposed transfer is unique and must be evaluated separately on its merits and for its potential impacts. *Accordingly, the Commission believes that Bulletin 160 should not speculate on specific sources for future transfers.*

9. Ground Water Overdraft. A number of speakers pointed out that the Draft does not adequately address the problem of continuing overdraft in the State. Some indicated that they believe the estimates in the San Joaquin and Tulare Lake hydrologic regions appear to be too low.

   - *The Commission recommends that the Draft's discussion of ground water overdraft be revised to make it clearer that continuing overdraft is a major problem which needs to be resolved. The Department should review the Plan's treatment of overdraft in the San Joaquin and Tulare Lake Basins and clarify the discussion of the bases of projected overdraft.*

   - Overdraft is an unfortunate result of existing practices; it is not a resource which can be included in water supply forecasts. *The Commission Recommends that overdraft should not be considered as a part of the future average year or drought year water supplies.*

   - The Commission concurs with several speakers who pointed out that, in many areas, increasing agricultural water use efficiency will reduce ground water recharge. Thus, in such areas where both surface water and ground water are used, increased agricultural water use efficiency may decrease conjunctive use potential.

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10. Long-term Carryover Storage.
    - While a number of Level I options will come into play in meeting California's present and future needs, the Commission believes that additional long-term carryover storage will be a key component in meeting future needs during critical drought periods. *The Commission recommends that the Department consider placing greater emphasis in Bulletin 160-93 on the need for additional long-term carryover storage both in surface reservoirs and in conjunctive operation of ground water basins.*
    - *The Commission also recommends that the Department consider seeking funding to investigate the feasibility of developing additional long term carryover storage on the west side of the Sacramento Valley.*

The Commission appreciates the opportunity to participate in the development of Bulletin 160. We commend the Department's staff for its substantial efforts in organizing the hearings, as well as the considerable amount of work in preparing the Draft. We look forward to publication of the final document.

Audrey Z. Tennis

Audrey Z. Tennis
Chair

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The Plan as a Whole

The majority of the comments about the plan as a whole centered around the use of the State Water Resources Control Board's Decision 1485 as the basis for assumptions about future allocations and water project operations. Many comments stated that DWR should instead be using current biological opinions for the winter-run salmon and Delta smelt, along with U.S. EPA-proposed water quality standards for the Sacramento-San Joaquin Delta, as the base case for projections of future operations and water allocations. Related to the comments about the base case were questions asking how the State Water Project would meet its contractual obligations in the future and what the State's role would be in implementing the options described in the plan.

Other comments received about the plan in general suggested that it should contain much more detailed information about specific projects or actions that should or could be implemented, their costs, who would manage or oversee the projects and programs, and how they would be financed. Several organizations suggested that the plan should include more information about agricultural drainage disposal problems, water recycling, desalination, and conjunctive use. Following are summaries of the most frequent comments and the sections or chapters where the subjects are addressed.

The Base Case

- ❑ Regulatory actions have already made the plan's base case obsolete. Today, biological opinions for the winter-run salmon and Delta smelt control operations of the State Water Project and Central Valley Project. [chs. 1, 2, and 12]
- ❑ Using the State Water Resources Control Board's Water Right Decision 1485 as the basis for this planning document presents an overly optimistic picture. Instead, use current biological opinions and U.S. Environmental Protection Agency standards for Delta water quality as the base case. [chs. 1, 2, and 12]

The State's Role

- ❑ The State should develop a management framework for implementing a long-term strategy for protecting the environment and meeting urban and agricultural water needs. At the least, the plan should include facilities' costs and financing alternatives for each area of the State and a discussion of the constraints to building facilities and of institutional impediments (State and federal) which need to be eliminated or modified. [chs. 2, 10, 11, and 12]
- ❑ The State's role in implementing Level I options is not clear. [*Options for Enhancing Water Supply Reliability*, *Water Supply Management Options*, and Table 11-5 in ch. 11]
- ❑ Nowhere in the document is there any assessment of institutional capability, no evaluation of the water planning process, nor consideration of the role of special districts in water management. [ch. 2; *Management of Ground Water Resources* and *Adjudicated Basins* in ch. 4; *Delta Planning Programs* and *Long-Term Delta Planning Programs* in ch. 10; and *Reliability Planning: Maintaining the Balance Between Water Supply* in ch. 11]
- ❑ The Bulletin 160 series has traditionally been the vehicle for the State to fulfill Article 16(c) of the State Water Service Contract wherefore the State is required to demonstrate its plan for developing project facilities and programs to meet the State Water Contractors' demands. The draft bulletin fails to satisfy this requirement. [ch. 2; *SWP Water Supply Augmentation* in the *Water Supply Management Options* in ch. 11]
- ❑ The plan should be revised to include a discussion of how the State will meet its State Water Project contractual obligations now and in the future. [*Water Supply Management Options* section in ch. 11]
- ❑ Be clear that local solutions are best achieved by local water agencies. [ch. 11]
- ❑ Encourage the development of consistent water reliability standards that are flexible enough to accommodate local, regional, and state water purveyors. [chs. 1 and 11]
- ❑ Tables should include years 2000 and 2010 projections. [chs. 1, 12, Vol. II *Summary*; demand tables in chs. 6 through 8; tables in Vol. II]
- ❑ At a minimum, DWR should aggressively pursue both short- and long-term water purchases. [ch. 11]

Specific Projects or Programs and Their Costs

- The plan does not contain specific projects or actions to be implemented. Detailed recommendations and specific implementation measures are lacking, especially in the areas of recycled water, conjunctive use, and most importantly, a physical "Delta fix." [chs. 10 and 11]

- The draft bulletin does not present a complete analysis of the costs of or required financing for assuring reliable water supplies or implementing Level I options, nor does it address the costs and consequences of not implementing Level I options. It contains no financing alternatives and no designations of authority. [chs. 10, 11, and 12]

- Agricultural drainage problems are not fully discussed, no solutions are discussed, and the disposal problem is not addressed. The plan should include a discussion of Kesterson Reservoir and the carrying of drainage water through Morro Bay to the ocean, and there should be more discussion about the San Joaquin Valley salinity problem. [*Management Programs* in ch. 2; ch. 5; *Drainage and Salinity* and *Drainage Reduction* in ch. 7; *Level II—Reliability Enhancement Options* in ch. 11]

- There is virtually no discussion of desalination. The State should provide leadership in developing this water source. [*Sea Water Desalination* in ch. 3; *Water Supply Management Options* in ch. 11; and Vol. II chs. on the North, Central, and South Coast regions]

- The bulletin makes no mention of potable reuse, which has a potential supply of more than one million acre-feet a year by 2020. [*Water Recycling* in ch. 3, *Level I and Level II—Reliability Enhancement Options* in ch. 11]

- The Water Recycling Act of 1991 should be included in Chapter 2. [*Water Use Efficiency* in ch. 2]

- The whole section on conjunctive use will benefit from a more complete exploration of this phenomenon. The draft bulletin's conjunctive use section sounds pessimistic and lacks any tables or figures on what conjunctive use efficiencies have been created in the past decade and what can be predicted in the future. [*Conjunctive Use Programs* in ch. 4]

Water Supply

A few comments asked why flood control had not been addressed, and several entities suggested that the bulletin's discussion of how the 1987-92 drought affected local communities be expanded. Following are summaries of the more general water supply comments.

- The draft bulletin focuses on water supply problems. Flooding problems for the state would seem to have a significant, if not comparable, average impact on the state. Planning for floods and droughts are not mutually exclusive. Maintaining flood storage capacity in reservoirs can reduce the amount of water supply available at the beginning of a drought. Land drainage and local flood control might also significantly affect aquifer recharge in some areas. A similar trade-off can arise between hydropower releases and water supply operations. [ch. 3]

- Not enough attention is being paid to local supplies being developed by many agencies throughout the state. Go out to local agencies and assess the projects. [chs. 3 and 11 and Vol. II]

Ground Water

- The importance of imported water supplies in reducing ground water overdraft is overstated as compared to contributions from local supplies. Prudent management of all available supplies during wet years [1980s] is as much responsible for reducing overdraft as imported supplies. [*Ground Water Overdraft* in ch. 4]

- The draft plan's ground water quantities are misleading, and the potential for recharge is overstated, especially when you consider how improved irrigation efficiencies and urban conservation measures reduce the amount of water available for recharge. The bulletin assumes there will be adequate surface water supplies, as well as conveyance capacity, to replenish ground water basins. However, there will be less surface water available for recharge, especially in areas depending on imported supplies. [ch. 4]

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- The draft update should mention and emphasize the impact of surface land use decisions on aquifer recharge. Recharging basins is not merely a matter of constructing facilities. It is also a matter of protecting the best existing natural recharge areas. [*Management of Ground Water Resources* in ch. 4]
- Table 4-2 as computed for the 1990 level is not realistic. [ch. 4]
- The total estimated extraction, perennial yield, overdraft, and usable storage for each hydrologic region should be listed in Table 4-2. [ch. 4]
- The impacts of current and future ground water substitution need to be addressed. [*Conjunctive Use Programs* in ch. 4]
- The plan's ground water overdraft projections are too low. To accept that 5.5 maf of applied ground water returns to the basins through reuse and deep percolation may be unrealistic and the reason for the error in ground water overdraft. A string of wet years in the early 1980s, an abundance of SWP water available to contractors, and the subsequent increase in artificial ground water recharge is responsible for much of the recovery. Over the last years of the 1987-92 drought there was some indication that our basins were receding and they may not completely recover. Expand the discussion about overdraft. [*Ground Water Overdraft* in ch. 4]
- By using ground water overdraft as a source of supply, rather than as a striking indicator of a chronic water shortage, the draft bulletin leads to the erroneous conclusion that current supplies can meet current demands. [*Existing Water Management Programs* and *California Water Balance* in ch. 12]
- The recommendations in the *Ground Water Supplies* chapter are simplistic and so general as to be of little value to policy makers. Specific ground water management recommendations need to be part of the plan. The whole section on conjunctive use would benefit from a more complete exploration of its potential. [*Conjunctive Use Programs* in ch. 4 and *Water Supply Management Options* in ch. 11]
- Discuss ways to simplify acquisition and delivery of available water to local ground water basins. [*Conjunctive Use Programs* in ch. 4 and *Water Supply Management Options* in ch. 11]
- The discussion of subsidence is inadequate. [ch. 4]

Water Use

Several organizations disagreed with the draft bulletin's water demand forecasts in each of the categories of use: urban, agricultural, and environmental. Comments also suggested that the bulletin's population forecasts were too high. Some commented that the reported water conservation potential for urban and agricultural uses was too high, while others stated that it was too low. In addressing the draft bulletin's forecasts about agricultural water use, several entities disagreed with the forecasted amount of acres that would be retired from agricultural production. Comments about environmental water use said that Wild and Scenic Rivers should not be included as an environmental water use and that the range of projected water use was either too high or too low. Other comments regarding the environment suggested that the draft bulletin had not adequately discussed non-water-project causes of fishery declines, how water project operations have benefited aquatic species, and the water use problems affecting the Salton Sea.

Urban Water Use

- The draft bulletin's urban water use projections are too high. [*Urban Water Use Forecasts* in ch. 6]
- The population forecast should be presented as a range and could be too high considering the current economic recession. [*Population Growth* in ch. 6]
- The bulletin's urban water conservation projections are too high. Show total applied water instead of net water demands. [*Urban Water Conservation* in ch. 6]
- It's possible to have increasing water demand without an increase in number of dwelling units. [*Per Capita Water Use* in ch. 6]
- The severity of drought impacts on many small communities is significantly understated and needs to be revised. [ch. 6 and *Economic Costs of Unreliability* in ch. 12]

Agricultural Water Use

- The draft plan's agricultural water use projections are too high. [*2020 Agricultural Water Demand* in ch. 7]
- The bulletin's agricultural water conservation projections are too high. Show total applied water instead of net water demands. [*Agricultural Water Conservation* in ch. 7]
- Include a range of up to 78-percent irrigation efficiency from the current level of 70 percent. The projected amount of water conserved from implementation of drainage programs is too low. Discuss the impact of water scarcity on cropping patterns and prices, and how pricing will affect agricultural water use. [*Agricultural Water Conservation* in ch. 7]
- The bulletin's view toward the potential for taking less productive irrigated acreage out of production is limited. In addition to discussing the impact of Central Valley urbanization, the bulletin should also address the effect of the increased cost of water in response to scarcity. [*Agricultural Acreage Forecast* and *2020 Agricultural Water Demand* in ch. 7]
- The coverage of agricultural water use is cast in a different, and less positive, light than urban or environmental water uses. Point out to readers that agriculture is but one of many industries in California, just as many of the water uses in the urban grouping are industrial. Agriculture is not the only industry which must solve challenging water problems for continued success. [ch. 7]
- Volume I contains only one paragraph on land retirement as an "option for reducing water supply and demand." It would not be unreasonable to retire between 100,000 to 200,000 acres of land in just the SWP service area within the next decade. The net water demand reduction resulting from retirement of these lands would provide approximately 400,000 acre-feet per year of firm yield, which is equal to the combined firm-yield from proposed Los Banos Grandes facilities and the completed Kern Water Bank. [*San Joaquin Valley Drainage Program* in ch. 7 and *Level II—Reliability Enhancement Options* in ch. 11]
- The only way that it makes any sense to retire that land is if you accept that there is no way to solve the drainage problem. Technically, the drainage problem is quite easy to resolve. The political decisions must be made and leadership must be provided to remove the institutional roadblocks and the $170 million-per-year economy can go on forever. [*San Joaquin Valley Drainage Program* in ch. 7 and *Level II—Reliability Enhancement Options* in ch. 11]
- No mention was made of the great environmental benefits that farms in this state provide to waterfowl and wildlife. Without the irrigation water to grow crops, waterfowl and wildlife on the farms would also suffer. No mention was made regarding the millions of jobs agriculture provides to the people of this state in agriculture-related industries. [chs. 7 and 8]
- Generally, the forecast that agricultural water use will decline by 2.3 maf annually by 2020 carries with it a potential danger. This prophecy could become self-fulfilling in that the State's attention will become more focused on providing for expanding environmental and urban uses and less focused on providing water for agricultural use. [*2020 Agricultural Water Demand* in ch. 7]

Environmental Water Use

- The tone toward environmental water use is negative; the plan seems to be blaming the environment for projected shortages. [chs. 1, 2, 8, and 12]
- Better environmental science is needed in assessing environmental water needs. The evaluation must be based upon data as sound as that used for urban and agricultural demands. The biological science used for fish flow and other decisions is questionable. Additional studies should be conducted prior to the next bulletin. [*Environmental Instream Flows* in ch. 8]
- The bulletin does not adequately explain the impact that nonproject factors have had on environmental declines in the Delta and fails to point out that, even with reductions in export pumping, environmental declines may continue because of the altered conditions in the Delta. [*Bay-Delta Estuary* in ch. 8]
- The draft update portrays environmental water needs on the basis that they are on the rise and that water to meet such needs will be forthcoming. Unlike the urban and agricultural

water use sections, however, there is no discussion of how economic factors will influence the State's ability to satisfy these needs. While the adverse impacts of water development for urban and agricultural uses are implicated, the benefits thereof for the environment (stored water and controlled releases), particularly in drought periods, are not discussed. [*Biological Resources and Processes* in ch. 8]

- The bulletin does not consider the environmental water needed for the Salton Sea. Although the conservation of irrigation flows historically discharging to the Salton Sea will lower the sea's levels, federal or State regulation requirements may impose mandatory levels for the Salton Sea and require an allocation of water from the Colorado River. [*Colorado River Region* in Vol. II]

Meeting California's Water Needs

Most of the comments received focused on the subject of meeting California's future water needs and on the draft bulletin's water supply and demand balance figures. Some commented about the reported benefits from the options, stating that the benefits were either too high or too low and that the costs of implementing options were not adequately analyzed. Other comments suggested that the bulletin was too optimistic about implementation of the options without a specific action plan.

The comments that addressed water transfers were almost evenly split between encouraging transfers and the consequences of water transfers. Some suggested that the draft plan did not sufficiently emphasize water transfers as an option, while others thought the Department of Water Resources was encouraging water transfers and should not depend too heavily on transfers to help close the gap between supply and demand. Several entities commented that the statewide water distribution system's capacity to implement more transfers is lacking.

Finally, some commented that the reported shortages in the water supply and demand balances were overstated, while others said the projected shortages would be more severe than the draft bulletin projected. Comments about the water balance also stated that the draft plan implied future shortages are manageable; quite a few expressed reservations about whether the reported options would be implemented and suggested the reported supply benefits from the options were overstated.

Many of the comments about supply indicated that the draft plan had not conveyed the immediacy of impending water shortages; some stated that the draft bulletin's projections of future supply shortages were too low, while others stated the shortages would not likely be as large as the bulletin projected.

The Sacramento–San Joaquin River Delta

- The costs of fixing the Delta, and of other water management actions, should be analyzed and shared by all causing parties and investors in the system on a prorated basis. Delta problems are caused by many different factors and entities, not just SWP and CVP diversions. [*Current Delta Regulatory Decision-Making Process* in ch. 10]

Options

- Projections for reclaimed water were low. [*Options for Enhancing Water Supply Reliability* in ch. 11]
- Urban drought rationing should not be considered a demand management strategy. The way in which the draft bulletin includes urban rationing understates the actual shortage remaining after implementing Level I options. Urban rationing should be considered a Level II option, not a Level I option. [ch. 11]
- The bulletin did not provide evidence or perform economic and environmental analyses to support the assertion that 10-percent urban rationing above the implementation of BMPs is "manageable" and would not cause significant economic impact. Therefore, urban rationing should not be considered a Level I option, which is defined as those "that have undergone extensive investigation and environmental analyses." [chs. 11 and 12]
- It is important to realize that future rationing will be difficult to implement as the so-called "fat" in water use is gone. A 10- or 15-percent water rationing in year 2000 is not going to be nearly as easy as a similar reduction in 1990, as mentioned in the draft update. [ch. 11]

- Implementation of options must begin now. [ch. 1]
- Quantify the economic impacts of unreliability. [ch. 11]
- State that implementation of Level I options is uncertain, and implementation for many of them has not begun. No specific agency has been designated to take charge of Bulletin 160-93 recommendations. There is no clear path of authority or direction to implement corrective action or even initiate its recommendations. [ch. 1]
- The accomplishments of supply augmentation options may be overstated. [ch. 11]
- The plan is too optimistic regarding the completion of the Los Banos Grandes project and the Kern Water Bank. [ch. 11]
- The effect of price increases is not mentioned as a management option. The demand projections assume constant prices yet demonstrate that water prices cannot remain constant. Recent changes to the Federal Reclamation Program have increased the price of water to CVP contractors; this is one example of government policy raising the price of water. The CVP contract renewal process and the upcoming regulations on the Reclamation Reform Act, which could affect the price of water to irrigation districts throughout the San Joaquin Valley are other important examples. Failure to make any attempt to factor in the effect of price increases will inevitably lead to an overstated gap between supplies and demands. At the very least, the bulletin should recognize the effect of price on demand and use available data, for example on agricultural and urban price elasticities, to estimate how future price increases can be expected to moderate demands. [chs. 11 and 12]
- Include analyses and cost estimates of Level II options. [ch. 11]
- DWR includes under Level I the Auburn Flood Control Dam, with no water supply savings from Folsom Reservoir. Included in Level II is reuse of brackish agricultural drainage and conjunctive use, which are both sources of supply in certain areas now. Why are these sources not considered Level I options? [ch. 11]
- The plan should recognize that the "ultimate potential" for recycled water production is the total waste water discharge stream. Today that figure is over 2.5 maf that is discharged to coastal waters. DWR is a partner with the USBR and a number of WateReuse member agencies in two studies whose objective is to take all of the unused waste water in California and put it to beneficial reuse. The water plan should show a range of 1.3 to 2.0 maf for the ultimate potential for water recycling. [ch. 11]
- The projections for reclaimed water are low compared to others we have seen and found credible. [ch. 11]
- Level I projections for recycled water use are based on Water Recycling 2000 projections for fresh water displaced. This is not an appropriate basis for projecting future recycled water supplies, and the 1993 WateReuse Association survey for "future water recycling potential" should be used instead. [ch. 11]
- Supplies from Level II options are not quantified in the water balance; the total need for Level II supplies is determined to be the shortage remaining after Level I. The Level I option of rationing is economically harmful; increased shortages remaining after Level I programs point to an increased need for Level II supplies. Inclusion of urban rationing as a Level II option instead of a Level I option would correct this problem. [ch.12]
- The figure of 1,140,200 as the ten-year average storage in New Melones is being used as the average river inflow and, thus, as the availability for allocation and distribution. There is no way that all the water behind New Melones could be totally allocated or used. There is a minimum pool that cannot ever be used. The storage, or average storage, is a function of the management of the reservoir and includes water that has already been allocated or held in reserve for later diversion and use by others. New Melones yield will be reduced due to: (1) the CVPIA and other environmental water requirements; (2) demand in the Stanislaus area; and (3) water used for San Joaquin River water quality purposes. [*San Joaquin River Region* in Vol. II]
- There was no mention of metering as an option; even if it were only partially implemented by 2020, it could provide additional savings. There are greater savings possible in the industrial/commercial and governmental sectors as well. Again, the effect of pricing increases is not factored in. [chs. 6 and 11]

- Suggest that there be State funding available for implementation of future State-mandated local water conservation programs. [ch. 6 and ch. 11]
- The regional water balance tables need a footnote stating, "Additional environmental water needs and potential rationing have not been included in the table; therefore, shortages during drought years may be larger." [ch. 12 and regional tables in Vol. II]

Water Transfers

- The plan does not include an adequate discussion of the potential for or consequences of water transfers. The bulletin includes only 800,000 af of transfers throughout the State, occurring only in drought years. The plan needs to recognize and include as a Level I option the potential of voluntary water transfers, particularly through the CVPIA. Proper incentives and means of mitigating the impacts associated with transfers should be developed. California should set the objective of achieving annual transfers to highest use in the range of 1 to 2 maf or more. [chs. 2 and 11]
- Water transfers cannot be counted as a solution because water cannot be transported easily or economically from a distant water source to the place of need; this is especially true of mountain areas. We are concerned that DWR's efforts would encourage and facilitate transfers on a regular basis. These transfers benefit other areas of the State at the expense of local economies of regions where water for transfers originate. Transfers of ground water or use of ground water in lieu of transferred surface water can increase overdraft conditions. [chs. 2 and 11]
- Make clear the implications or limitations of area-of-origin rights. Bulletin 160-93 should state that there is a history of water rights, agreements, and laws that protect the Sacramento Valley as an area of origin from any water leaving the watershed that is otherwise needed to meet environmental and other beneficial uses. [ch. 2]
- Water transfers should be included as a supply option for the State Water Project. [ch. 11]
- The State should establish authority to allocate funds to reimburse transfer areas for third-party impacts due to water transfers. Failure to establish policy that reimburses transfer areas for third-party impacts may undermine the potential for future transfer arrangements. [ch. 2]
- DWR, SWRCB, and USBR must develop reasonable procedures for water transfers. Proposed legislation limiting transfers to ten years will have to be changed. [ch. 2]
- Existing water conveyance facilities have no extra capacity for these transfers and additional conveyance facilities are needed. Further, transfers may be limited by environmental requirements and other restrictions and opposition. [ch. 11]

Water Supply and Demand Balance

- The plan needs to include a best-estimated water balance analysis of the Delta situation as of December 15, 1993. It presents water balance data as averages on both statewide and regional bases; this masks the severity of the water shortage situations in some local areas. [chs. 1 and 12, and Vol. II *Summary*]
- The gap between supply and demand is not likely to be nearly as large as is projected, and with proper planning, it may not exist at all. [chs. 1, 12, and Vol. II *Summary*]
- The plan contains a contradiction. It concludes that water is not quite scarce in the State but that there is not enough to go around. The only way the projections make sense is if water crises are constant. [chs. 1 and 12 and Vol. II *Summary*]
- The supply accomplishments shown for Level I and Level II supply augmentation options were taken from previous studies. They were determined based on operational and regulatory constraints in effect at the time those studies were completed. Constraints not anticipated in those studies have been imposed, and constraints which may yet be imposed, are likely to reduce the supply benefits shown for some options. The biological opinions, the CVPIA, and more stringent drinking water quality standards may not only reduce existing supplies, but may also reduce yield of future supply options, potentially making some options infeasible. Shortages shown after completion of Level I options may be understated. [chs. 11 and 12]

- The need for additional supplies should be more strongly stated. [chs. 1 and 12 and Vol. II *Summary*]
- The plan shows worsening shortages by 2020; these shortages are here today. [chs. 1 and 12 and Vol. II *Summary*]
- The supply shortages in the draft plan are not likely to be as large as projected. [ch. 1, 12, and Vol. II *Summary*]
- The draft update overestimated drought water supply and did not reflect what really happened. [chs. 1 and 12; Vol. II *Summary*]

Miscellaneous

Some of the more uncommon comments were repeated, in slightly different wordings, only a few times. Topics addressed by these comments were impacts of less water for agriculture, carriage water and reverse flow in the Delta, the draft bulletin's categories of water use, and the approach used in analyzing water demand.

- Is it possible for DWR to: (1) compute the mathematical probability of interruptions in irrigation water flows for 1995–2020; and (2) integrate this data into a sensitivity analysis measuring the resultant impact on major California agricultural commodities which generate annual sales approaching $18 billion? [ch. 7]
- The role of reverse flow in moving salt into the Delta is greatly overestimated by current models. Draft Bulletin 160-93 notes this to a certain extent where it states: "the massive amount of tidal action dwarfs the actual fresh water outflow and considerably complicates the reverse flow issue." Inclusion of the carriage water model in DWR's planning models without proper analysis of the underlying uncertainties can lead to erroneous conclusions. [*Reverse Flow and Carriage Water* in ch. 10]
- These three groupings (urban, agricultural, environmental) are used as a convenient means to depict the major water uses which are supposedly competing for a limited supply. Describing present and future uses according to these groupings can involve policy implications which are not properly part of the subject material of DWR's Bulletin 160 series. Part III should be reviewed with the intention of rephrasing those sections which discuss policy implications regarding three water use groupings. [Part III]
- We recommend that a clear statement be included in the preface to convey that the bulletin reflects the opinions of DWR and the present Governor's application of his water policy. [*Foreword* and ch. 1]
- The approach in providing only the gross numbers for the entire Central Coast Area makes it difficult to check or comment on the accuracy of the numbers used in the tables in both volumes. Break down the water demand and overdraft numbers by detailed analysis units. [*Central Coast Region* in Vol. II]
- All the regional water balance tables in Volume II should include a footnote stating that unlike the statewide water balance, shortages indicated in the regional tables do not include added environmental needs and drought-year urban rationing. [Vol. II]

Locations of Department of Water Resources district offices:

Northern District
2440 Main Street
Redding, CA 96080-2398
(916) 529-7300

Central District
3251 S Street
Sacramento, CA 95816-7017
(916) 445-683

San Joaquin District
3374 East Shields Avenue
Fresno, CA 93726-6990
(209) 445-5443

Southern District
770 Fairmount Avenue
Glendale, CA 91203-1035
(818) 543-4600

Glossary

acre-foot (af) a quantity or volume of water covering one acre to a depth of one foot; equal to 43,560 cubic feet or 325,851 gallons.

active storage capacity the total usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity.

afterbay a reservoir that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.

agricultural drainage (1) the process of directing excess water away from root zones by natural or artificial means, such as by using a system of pipes and drains placed below ground surface level; also called subsurface drainage; (2) the water drained away from irrigated farmland.

alluvium a stratified bed of sand, gravel, silt, and clay deposited by flowing water.

anadromous pertaining to fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn.

angler-day the time spent fishing by one person for any part of a day.

applied water demand the quantity of water delivered to the intake of a city's water system or factory, the farm headgate, or a marsh or other wetland, either directly or by incidental drainage flows (this is primarily water for wildlife areas). For instream use, it is the portion of the stream flow dedicated to instream use or reserved under the federal or State Wild and Scenic Rivers acts.

aquatic algae microscopic plants that grow in sunlit water containing phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain.

aquifer a geologic formation that stores and transmits water and yields significant quantities of water to wells and springs.

arid a term describing a climate or region in which precipitation is so deficient in quantity or occurs so infrequently that intensive agricultural production is not possible without irrigation.

artificial recharge addition of surface water to a ground water reservoir by human activity, such as putting surface water into spreading basins. See also *ground water recharge, recharge basin.*

average annual runoff for a specified area is the average value of annual runoff amounts calculated for a selected period of record that represents average hydrologic conditions.

average year water demand demand for water under average hydrologic conditions for a defined level of development.

average year supply the average annual supply of a water development system over a long period. For this report, the State Water Project and Central Valley Project average year supply is the average annual delivery capability of the projects over a 70-year study period (1922-91). For a local project without long-term data available, it is the annual average deliveries of the project during the 1984–1986 period. For dedicated natural flow, it is the long-term average natural flow for wild and scenic rivers or it is environmental flows as required for an average year under specific agreements, water rights, court decisions, and congressional directives.

benthic invertebrates aquatic animals without backbones that dwell on or in the bottom sediments of fresh or salt water. Examples: clams, crayfish, and a wide variety of worms.

best management practice (BMP) an urban water conservation measure that the California Urban Water Conservation Coalition agrees to implement among member agencies.

biota all living organisms of a region, as in a stream or other body of water.

brackish water water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water.

bromide a salt which naturally occurs in small quantities in sea water; a compound of bromine.

chaparral a major vegetation type in California characterized by dense evergreen shrubs with thick, hardened leaves.

closed basin a basin whose topography prevents surface outflow of water. It is considered to be hydrologically closed if neither surface nor underground outflow of water can occur.

confined aquifer a water-bearing subsurface stratum that is bounded above and below by formations of impermeable, or relatively impermeable, soil or rock.

conjunctive use the operation of a ground water basin in combination with a surface water storage and conveyance system. Water is stored in the ground water basin for later use by intentionally recharging the basin during years of above-average water supply.

Decision 1485 operating criteria standards for operating water project facilities under Water Right Decision 1485 regarding the Sacramento-San Joaquin Delta and Suisun Marsh, adopted by the State Water Resources Control Board, August 1978.

dedicated natural flow river flows dedicated to environmental use.

deep percolation the percolation of water through the ground and beyond the lower limit of the root zone of plants into a ground water aquifer.

demand management alternatives water management programs—such as water conservation, drought rationing, or rate incentive programs—that reduce demand for water.

dependable supply the annual average quantity of water that can be delivered during a drought period.

depletion the water consumed within a service area and no longer available as a source of supply. For agriculture and wetlands, it is ETAW (and ET of flooded wetlands) plus irrecoverable losses. For urban water use, it is ETAW (water applied to landscaping or home gardens), sewage effluent that flows to a salt sink, and incidental ET losses. For instream use, it is the amount of dedicated flow that proceeds to a salt sink and is not available for reuse.

desalination a process that converts sea water or brackish water to fresh water or an otherwise more usable condition through removal of dissolved solids; also called *desalting.*

detailed analysis unit (DAU) the smallest study area used by Department of Water Resources for analyses of water demand and supply. Generally defined by hydrologic features or boundaries of organized water service agencies. In the major agricultural areas, a DAU typically includes 100,000 to 300,000 acres.

discount rate the interest rate used in evaluating water (and other) projects to calculate the present value of future benefits and future costs or to convert benefits and costs to a common time basis.

dissolved organic compounds carbon substances dissolved in water.

dissolved oxygen (DO) the oxygen dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation.

distribution uniformity (DU) the ratio of the average low-quarter depth of irrigation to the average depth of irrigation, for the entire farm field, expressed as a percent.

double cropping the practice of producing two or more crops consecutively on the same parcel of land during a 12-month period. Also called multi-cropping.

drainage basin the area of land from which water drains into a river; for example, the Sacramento River Basin, in which all land area drains into the Sacramento River. Also called, "catchment area," "watershed," or "river basin."

drought condition hydrologic conditions during a defined drought period during which rainfall and runoff are much less than average.

drought year supply the average annual supply of a water development system during a defined drought period. For this report, the drought period is the average of water years 1990 and 1991. For dedicated natural flow, it is the average of water years 1990 and 1991 for wild and scenic rivers, or it is environmental flows as required under specific agreements, water rights, court decisions, and congressional directives.

ecology the study of the interrelationships of living organisms to one another and to their surroundings.

economic demand the consumer's willingness and ability to purchase some quantity of a commodity based on the price of that commodity.

ecosystem recognizable, relatively homogeneous units, including the organisms they contain, their environment, and all the interactions among them.

efficient water management practice (EWMP) an agricultural water conservation measure that water suppliers can implement. EWMPs are organized into three categories: Irrigation Management Services; Physical and Structural Improvements; and Institutional Adjustments.

effluent waste water or other liquid, partially or completely treated or in its natural state, flowing from a treatment plant.

entrapment zone the portion of the Sacramento-San Joaquin Bay/Delta estuary where seaward-flowing fresh water overlays more dense, saline ocean water resulting in a two-layer mixing zone characterized by flocculation, aggregation, and accumulation of suspended materials from upstream.

environment the sum of all external influences and conditions affecting the life and development of an organism or ecological community; the total social and cultural conditions.

environmental water the water for wetlands, for the instream flow in a major river, or for a designated wild and scenic river (based on unimpaired flow).

estuary the lower course of a river entering the sea influenced by tidal action where the tide meets the river current.

evapotranspiration (ET) the quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces. Quantitatively, it is usually expressed in terms of depth of water per unit area during a specified period of time.

evapotranspiration of applied water (ETAW) the portion of the total evapotranspiration which is provided by irrigation.

firm yield the maximum annual supply of a given water development that is expected to be available on demand, with the understanding that lower yields will occur in accordance with a predetermined schedule or probability. See also *dependable supply, project yield.*

forebay a reservoir or pond situated at the intake of a pumping plant or power plant to stabilize water levels; also a storage basin for regulating water for percolation into ground water basins.

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fry a recently hatched fish.

gray water waste water from a household or small commercial establishment. Graywater *does not* include water from a toilet, kitchen sink, dishwasher, washing machine, or water used for washing diapers, etc.

gross reservoir capacity the total storage capacity available in a reservoir for all purposes, from the streambed to the normal maximum operating level. Includes dead (or inactive) storage, but excludes surcharge (water temporarily stored above the elevation of the top of the spillway).

ground water water that occurs beneath the land surface and completely fills all pore spaces of the alluvium, soil, or rock formation in which it is situated.

ground water basin a ground water reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir. In some cases, the boundaries of successively deeper aquifers may differ and make it difficult to define the limits of the basin.

ground water overdraft the condition of a ground water basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average.

ground water prime supply the long-term average annual percolation into the major ground water basins from precipitation falling on the land and from flows in rivers and streams.

ground water recharge increases in ground water storage by natural conditions or by human activity. See also *artificial recharge.*

ground water storage capacity the space or voids contained in a given volume of soil and rock deposits.

ground water table the upper surface of the zone of saturation, except where the surface is formed by an impermeable body.

hardpan a layer of nearly impermeable soil beneath a more permeable soil, formed by natural chemical cementing of the soil particles.

head ditch the water supply ditch at the head end of an irrigated field.

hydraulic barrier a barrier developed in the estuary by release of fresh water from upstream reservoirs to prevent intrusion of sea water into the body of fresh water.

hydrologic balance an accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.

hydrologic basin the complete drainage area upstream from a given point on a stream.

hydrologic region a study area, consisting of one or more planning subareas.

instream use use of water that does not require diversion from its natural watercourse. For example, the use of water for navigation, recreation, fish and wildlife, aesthetics, and scenic enjoyment.

irrecoverable losses the water lost to a salt sink or lost by evaporation or evapotranspiration from a conveyance facility, drainage canal, or in fringe areas.

irrigated acreage land area that is irrigated, which is equivalent to total irrigated crop acreage minus the amount of acreage that was double cropped.

irrigation efficiency the efficiency of water application and use. Computed by dividing evapotranspiration of applied water by applied water and converting the result to a percentage. Efficiency can be computed at three levels: farm, district, or basin.

irrigation return flow applied water that is not transpired, evaporated, or deep-percolated into a ground water basin but that returns to a surface water supply.

land retirement (as used in this report) taking land out of agricultural production by leaving it fallow or letting it return to a natural state.

land subsidence the lowering of the natural land surface in response to earth movements; lowering of fluid pressure (or lowering of ground water level); removal of underlying supporting materials by mining or solution of solids, either artificially or from natural causes; compaction caused by wetting (hydrocompaction); oxidation of organic matter in soils; or added load on the land surface.

laser land leveling use of instruments featuring laser beams to guide earth-moving equipment for leveling land for surface-type irrigation.

leaching the flushing of salts from the soil by the downward percolation of applied water.

leaching requirement the theoretical amount of irrigation water that must pass (leach) through the soil beyond the root zone to keep soil salinity within acceptable levels for sustained crop growth.

level of development in a planning study, the practice of holding constant the population, irrigated acreage, industry, and wildlife so that hydrologic variability can be studied to determine adequacy of supplies.

maximum contaminant level (MCL) the highest concentration of a constituent in drinking water permitted under federal and State Safe Drinking Water Act regulations.

megawatt one million watts; a measure of power plant output.

milligrams per liter (mg/L) the weight in milligrams of any substance dissolved in one liter of liquid; nearly the same as parts per million.

mineralization the process whereby concentrations of minerals, such as salts, increase in water, often a natural process resulting from water dissolving minerals found in rocks and soils through which it flows.

moisture stress a condition of physiological stress in a plant caused by lack of water.

multipurpose project a project designed to serve more than one purpose. For example, one that provides water for irrigation, recreation, fish and wildlife, and, at the same time, controls floods or generates electric power.

National Pollutant Discharge Elimination System (NPDES) a provision of Section 402 of the federal Clean Water Act of 1972 that established a permitting system for discharges of waste materials to water courses.

natural flow the flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.

net water demand (net water use) the amount of water needed in a water service area to meet all requirements. It is the sum of evapotranspiration of applied water (ETAW) in an area, the irrecoverable losses from the distribution system, and the outflow leaving the service area; does not include reuse of water within a service area (such as reuse of deep-percolated applied water or use of tail water).

nonpoint source waste water discharge other than from point sources. See also *point source.*

nonreimbursable costs project costs allocated to general statewide or national beneficial purposes and funded from general revenues.

normalized demand the process of adjusting actual water use in a given year to account for unusual events such as dry weather conditions, government interventions for agriculture, rationing programs, or other irregularities.

overdraft See *ground water overdraft.*

pathogens any viruses, bacteria, or fungi that cause disease.

peak load (power) the maximum electrical energy used in a stated period of time. Usually computed over an interval of one hour that occurs during the year, month, week, or day. The term is used interchangeably with peak demand.

perched ground water ground water supported by a zone of material of low permeability located above an underlying main body of ground water with which it is not hydrostatically connected.

per capita water use the water produced by or introduced into the system of a water supplier divided by the total residential population; normally expressed in gallons per capita per day (gpcd).

percolation the downward movement of water through the soil or alluvium to a ground water table.

perennial yield the maximum quantity of water that can be annually withdrawn from a ground water basin over a long period of time (during which water supply conditions approximate average conditions) without developing an overdraft condition. Sometimes referred to as sustained yield.

permeability the capability of soil or other geologic formations to transmit water.

phytoplankton minute plants, usually algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

planning subarea (PSA) an intermediately-sized study area consisting of one or more detailed analysis unit(s).

point source a specific site from which waste or polluted water is discharged into a water body, the source of which can be identified.

pollution (of water) the alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.

project yield the water supply attributed to all features of a project, including integrated operation of units that could be operated individually.

pump lift the distance between the ground water table and the overlying land surface.

pumped storage project a hydroelectric powerplant and reservoir system using an arrangement whereby water released for generating energy during peak load periods is stored and pumped back into the upper reservoir, usually during periods of reduced power demand.

pumping-generating plant a plant at which the turbine-driven generators can also be used as motor-driven pumps.

recharge basin a surface facility, often a large pond, used to increase the percolation of surface water into a ground water basin.

recreation-day participation in a recreational activity, such as skiing, biking, hiking, fishing, boating, or camping, by one person for any part of a day.

recycled water urban waste water that becomes suitable, as a result of treatment, for a specific direct beneficial use. See also *water recycling.*

return flow the portion of withdrawn water not consumed by evapotranspiration or system losses which returns to its source or to another body of water.

reuse the additional use of previously used water.

reverse osmosis method of removing salts from water by forcing water through a membrane.

riparian located on the banks of a stream or other body of water.

riparian vegetation vegetation growing on the banks of a stream or other body of water.

runoff the surface flow of water from an area; the total volume of surface flow from an area during a specified time.

salinity generally, the concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids), electrical conductivity, or osmotic pressure. Where sea water is known to be the major source of salt, salinity is often used to refer to the concentration of chlorides in the water. See also *total dissolved solids.*

salinity intrusion the movement of salt water into a body of fresh water. It can occur in either surface water or ground water bodies.

salt sink a body of water too salty for most freshwater uses.

salt-water barrier a physical facility or method of operation designed to prevent the intrusion of salt water into a body of fresh water.

seasonal application efficiency (SAE) the sum of evapotranspiration of applied water and leaching requirement divided by the total applied water, expressed as a percentage.

$$\mathrm{SAE} = \frac{\mathrm{ETAW} + \mathrm{LR}}{\mathrm{AW}}$$

secondary treatment in sewage, the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems. Secondary treatment is usually carried out through the use of trickling filters or by the activated sludge process.

sediment soil or mineral material transported by water and deposited in streams or other bodies of water.

seepage the gradual movement of a fluid into, through, or from a porous medium.

self-produced water a water supply (usually from wells) developed and used by an individual or entity. Also called "self-supplied water."

service area the geographical land area served by a distribution system of a water agency.

sewage the liquid waste from domestic, commercial, and industrial establishments.

soluble minerals naturally occurring substances capable of being dissolved.

spawning the depositing and fertilizing of eggs (or roe) by fish and other aquatic life.

spreading basin See *recharge basin.*

spreading grounds See *recharge basin.*

streamflow the rate of water flow past a specified point in a channel.

striped bass index in the San Francisco Bay/Sacramento-San Joaquin Delta system, a number representing the abundance of striped bass.

subsurface drainage See *agricultural drainage.*

supply augmentation alternatives water management programs—such as conjunctive use, water banking, or water project facility expansion—that increase supply.

surface supply water supply from streams, lakes, and reservoirs.

surface water treatment rule federal regulation promulgated on June 29, 1989 (54 FR 124) requiring filtration and rigorous disinfection of surface water supplies and ground water supplies directly under the influence of surface water.

surplus water developed water supplies in excess of contract entitlement or apportioned water.

tail water applied irrigation water that runs off the end of a field. Tail water is not necessarily lost; it can be collected and reused on the same or adjacent fields.

tertiary treatment in sewage, the additional treatment of effluent beyond that of secondary treatment to obtain a very high quality of effluent for reuse.

total dissolved solids a quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter. Abbreviation: TDS. See also *salinity*.

transpiration an essential physiological process in which plant tissues give off water vapor to the atmosphere.

trihalomethane (THM) chlorinated halogen compounds such as chloroform, carbon tetrachloride and bromoform, formed by reactions between carbonaceous matter and chlorine or bromine.

visitor-day See *recreation-day*.

waste water the used water, liquid waste, or drainage from a community, industry, or institution.

water conservation reduction in applied water due to more efficient water use such as implementation of Urban Best Management Practices or Agricultural Efficient Water Management Practices. The extent to which these actions actually create a savings in water supply depends on how they affect net water use and depletion.

water demand schedule a time distribution of the demand for prescribed quantities of water for specified purposes. It is usually a monthly tabulation of the total quantity of water that a particular water user intends to use during a specified year.

water quality used to describe the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose or use.

water reclamation as used in this report, includes water recycling, seawater desalting, ground water reclamation, and desalting agricultural brackish water.

water recycling the treatment of urban waste water to a level rendering it suitable for a specific, direct, beneficial use.

water right a legally protected right to take possession of water occurring in a natural waterway and to divert that water for beneficial use.

water service reliability the degree to which a water service system can successfully manage water shortages.

watershed See *drainage basin*.

water table See *ground water table*.

water year a continuous 12-month period for which hydrologic records are compiled and summarized. In California, it begins on October 1 and ends September 30 of the following year.

Abbreviations and Acronyms

ACFC&WCD Alameda County Flood Control and Water Conservation District

af acre-feet

AW applied water

BDOC Bay-Delta Oversight Council

BMP Best Management Practice

CCWD Calaveras County Water District

CEC California Energy Commission

CMO Crop Market Outlook

CVP Central Valley Project

CCWD Contra Costa Water District

CVPIA Central Valley Project Improvement Act

CVWD Coachella Valley Water District

CVWUC Central Valley Water Use Committee

D-1485 State Water Resources Control Board Water Right Decision 1485

DAU detailed analysis unit

DBPs disinfection byproducts

DBCP dibromochloropropane

DFG California Department of Fish and Game

DWA Desert Water Agency

DWR California Department of Water Resources

EBMUD East Bay Municipal Utility District

EDCWA El Dorado County Water Agency

EDF Environmental Defense Fund

EID El Dorado Irrigation District

EPA federal Environmental Protection Agency

ESA Endangered Species Act

ETAW evapotranspiration of applied water

EWMP Efficient Water Management Practice

FERC Federal Energy Regulatory Commission

GCID Glenn-Colusa Irrigation District

gpcd gallons per capita daily

HBMWD Humboldt Bay Municipal Water District

HLWA Honey Lake Wildlife Area

IID Imperial Irrigation District

IFIM Instream Flow Incremental Methodology

LADWP Los Angeles Department of Water and Power

LR leaching requirement

maf million acre-feet

MCL maximum contaminant level

MID Merced Irrigation District or Modesto Irrigation District

MCWRA Monterey County Water Resources Agency

MMWD Marin Municipal Water District

MOU memorandum of understanding

MRWPCA Monterey Regional Water Pollution Control Agency

MWDSC Metropolitan Water District of Southern California

NMFS National Marine Fisheries Service

NMWD North Marin Water District

NPDES National Pollutant Discharge Elimination System

OCID Orange Cove Irrigation District

PCE perchlorethylene

PCWA Placer County Water Agency

PG&E Pacific Gas and Electric Company

P.L. Public Law

PSA planning subarea

PVWMA Pajaro Valley Water Management Agency

RCD resource conservation district

SAE seasonal application efficiency

SBVMWD San Bernardino Valley Municipal Water District

SCE Southern California Edison Company

SCVWD Santa Clara Valley Water District

SCWA Solano County Water Agency or Sonoma County Water Agency

SDCWA San Diego County Water Authority

SDWA South Delta Water Agency

SFWD San Francisco Water District

SJWA San Jacinto Wildlife Area

SJVDP San Joaquin Valley Drainage Program

SJRMP San Joaquin River Management Program

SMUD Sacramento Municipal Utility District

SNWA Southern Nevada Water Authority

SSWD South Sutter Water District

SWP State Water Project

SWRCB State Water Resources Control Board

SWTR federal Surface Water Treatment Rule

TCE trichlorethylene

TDS total dissolved solids

THM trihalomethane

TID-MID Turlock Irrigation District and Modesto Irrigation District

TROA Truckee River Operating Agreement

UCD University of California at Davis

USBR U.S. Bureau of Reclamation, Department of the Interior

USCE U.S. Corps of Engineers, Department of the Army

USFWS U.S. Fish and Wildlife Service

WSD water storage district

WSMP water storage management plan

YCFCWCD Yolo County Flood Control and Water Conservation District

YCWA Yuba County Water Agency

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